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Seafood . . .

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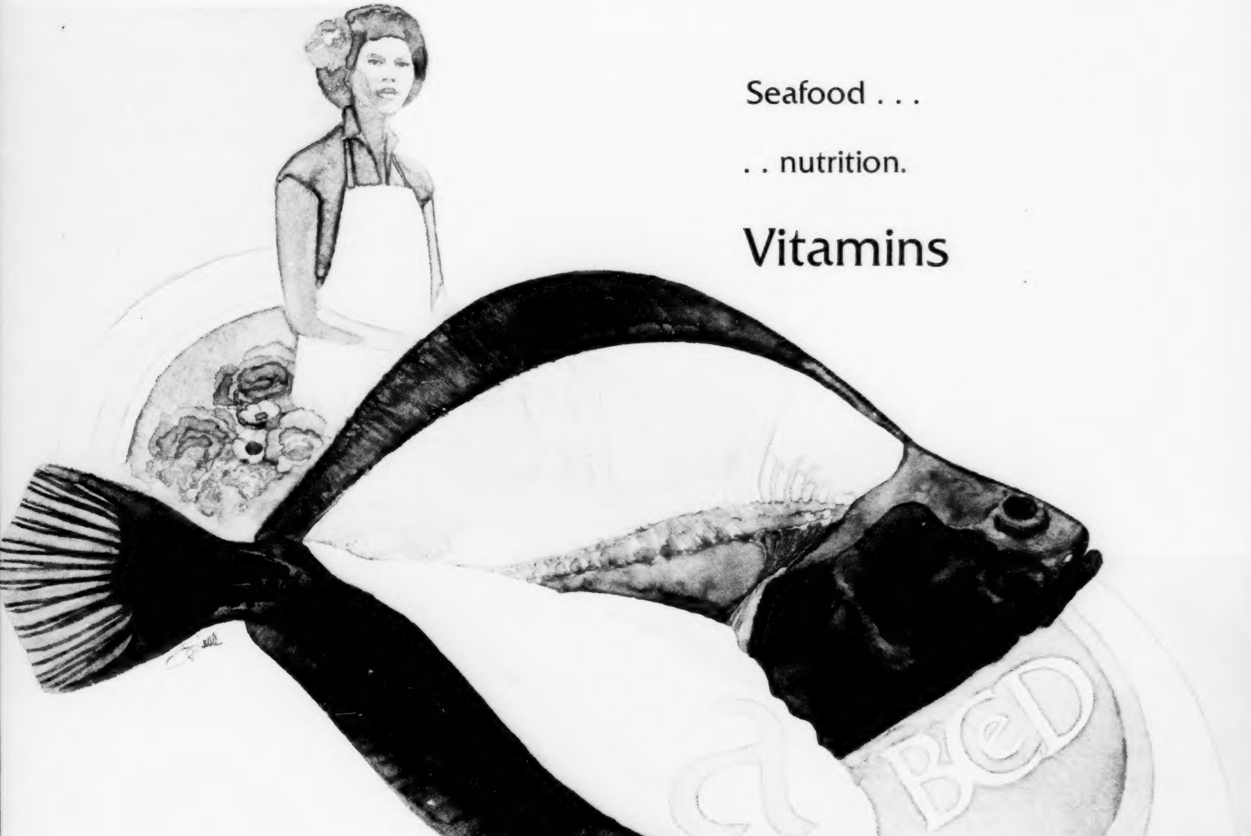
Vitamins



Marine Fisheries Review

Vol. 40, No. 12
December 1978

CONTENTS

Articles

Departments

Cover: The vitamins in fishes (see article on page 1) are reflected in the illustration by Harold Spiess.

U.S. DEPARTMENT OF COMMERCE
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MFR PAPER 1355

Composition of the Edible Portion of Raw (Fresh or Frozen) Crustaceans, Finfish, and Mollusks. IV. Vitamins

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PAULINE R. FONCANNON, and DAVID H. BUZZELL

ABSTRACT—This report summarizes data from 157 publications referring to the vitamin content of commonly eaten seafoods. Included are references to vitamins A, D, and E, choline, ascorbic acid, inostitol, biotin, thiamin, riboflavin, niacin, pyridoxine, folic acid, vitamin B_{12}, and pantothenic acid.

INTRODUCTION

In Part I, Sidwell et al. (1974) described the data bank being established at the Southeast Fisheries Center College Park Laboratory[1] of the National Marine Fisheries Service, NOAA, College Park, Md. The objectives of the data bank project are: 1) To develop a comprehensive, systematic data retrieval system containing available information on the chemical and nutritional composition of fish and fishery products; 2) to publish information on the nutrients found in fishery products based on a wide survey of the literature and 3) to point out aspects of chemical composition of fish which need further investigation. Part I also summarized the data on the content of protein, fat, moisture, ash, carbohydrate, energy (calories), and cholesterol in commonly eaten seafoods.

In Part II, Sidwell et al. (1977) reviewed the data on the concentration of sodium, potassium, calcium, phosphorus, chlorine, and magnesium found in edible portions of seafood.

In Part III, Sidwell et al. (1978) assembled the data from literature on the concentrations of various microelements (trace elements) in seafood.

This paper, Part IV, summarizes the data on the various vitamins in fish and shellfish muscle. There is a need in the medical community for such information, e.g., in the evaluation of nutritional aspects and in the calculation of special diets. Industry can use the data to encourage the use of nutritional labeling. And the nutrition-conscious consumer wants to know the nutritional aspects of fish.

RESULTS AND DISCUSSION

In this report we assembled, from 157 references, data on the vitamins present in the flesh of 140 different species of aquatic animals.

The averages and ranges for each vitamin were calculated from the data reported by various investigators. These data were in the form of an average based on multiple determinations, or were reported as individual values from which an average could be calculated. Regardless, only averages were used to calculate the overall average, standard error of the mean, and range appearing in Tables 1 and 2. With the aforementioned statistics is the number of averages used to make the statistical calculations.

A limited number of analyses are available for many species of finfish or shellfish listed in Tables 1 and 2. A number of commonly caught species have not been analyzed for vitamin content. Wherever the information for a specific fish and/or vitamin is limited, the recorded value should be regarded only as an estimate of what can be expected. More data are necessary to obtain a value that has a higher degree of reliability.

As noted in Tables 1 and 2, the range of values for each of the vitamins in the flesh of the same species of animal is quite large. A portion of this variation within each species is undoubtedly associated with seasonal and biological differences, e.g., size of the animal, its age, sex, degree of sexual maturation, and method of handling the fish after it left the water and before the flesh was analyzed for the various vitamins. Also, some of the variation may be related to the technique used in the preparation of the sample before it is analyzed or the method of analysis used by the investigator.

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[1]Relocated in 1978, this is now the Charleston Laboratory, Southeast Fisheries Center, NMFS, NOAA, P.O. Box 12607, Charleston, SC 29412.

Table 1 lists the values for the fat-soluble vitamins A, D, and E, and the water soluble vitamins choline, ascorbic acid, inositol, and biotin. The amount of vitamin A in the flesh is associated with the amount of fat present in the flesh. Dark flesh is higher in fat than the light; therefore, there is more vitamin A in the dark meat. Vitamin A is not synthesized by the aquatic animal, but is derived from the carotene in its foods. If the whole mollusk is used in the analyses, the amount of vitamin A will be influenced by the plankton in the intestinal tract of the animal.

So little data are reported on the amount of vitamin E present in the flesh of finfish or shellfish that no conclusion can be made. There is little evidence that more vitamin E is present in the flesh of the fatty fish.

The information on the three B-vitamins—choline, inositol, and biotin—is minimal. As noted in Table 1, raw fish flesh does contain varying amounts of vitamin C. In some fish, the amounts are large enough that one serving (100 g or 3.5 ounce) will make a sizable contribution to a person's daily requirement, ranging from 30 mg to 100 mg depending upon a person's body size.

Of the B-vitamins listed in Table 2, riboflavin and niacin are present in significant amounts; therefore, a serving of fish will contribute considerably to a person's daily needs. Thiamin content is found in notably lesser amounts. Mollusks, especially oysters, are rich in Vitamin B_{12}.

The data summarized in this report will provide the medical community with an estimate of the various vitamins found in seafoods for the calculations of special diets. The information will be also appreciated by those concerned with consumer education.

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Continued on page 14.

Table 1.—Composition of the edible portion of raw (fresh or frozen) crustaceans, finfish, and mollusks. IV. Vitamins: A, D, E, choline, ascorbic acid, inositol, and biotin.

	A (I.U.)	D (I.U.)	E (mg)	Choline (mg)	Ascorbic acid (mg)	Inositol (μg)	Biotin (μg)	References
	per 100 g							
Abalone Haliotidae spp.	61 1							64
Amberjack and yellowtail *Seriola* spp.	[1]11±11 [2]0-22 [3]2	27±27 0-53 2	0.2±0 0.1-0.2 5	59 1	2.0±0.4 1.0-2.8 4			48, 55, 61, 62, 80, 103
Anchovies Engraulidae spp.	635 1							33
Barracudas Sphyraenidae spp.	51±7 40-62 3							57
Basses, sea Serranidae spp.	129±36 61-184 3							33, 57
Breams and porgies Sparidae spp.	53±31 7-144 4			31±4 18-39 3	2.9±0.5 0.4-1.7 4			33, 57, 61, 80, 82
Butterfishes Stromateidae spp.	182 1							69
Carp Cyprinidae spp.	262±127 29-1,020 8		630 1	2.0±0.4 0.6-3.1 6	18.5±6.9 0-160 24	8,894±823 7,585-11,000 4		36, 55, 57, 61, 62, 67, 81, 83, 87, 122, 130, 140
Catfishes, airbreathing Clariidae spp.	633 1							33
Catfishes, freshwater Ictaluridae spp.		500 1			9.3±1.9 6.0-12.5 4	6,620 1		36, 122, 130
Catfishes, sea Ariidae spp.	96 1				7.8±3.9 0-11.7 3			33, 36, 83, 122
Characins Characidae spp.					0±0 0-0 2			27
Cichlids Cichlidae spp.	58±41 17-99 2				1.0 1			6, 33, 80
Clams, mactra Mactridae spp.	33 1							80
Clams, razor Solenidae spp.	64±47 17-110 2							80, 81
Clams, Veneridae Veneridae spp.	1,124±237 887-1,360 2				14.2±1.1 13.1-15.2 2			33, 44, 114
Clams Miscellaneous species	370±172 11-1,317 7	4.4±4.4 0-8.8 2	0.5±0.2 0-0.9 4	58±0 58-58 2	11.2±3.6 2.0-30.0 7		2.3 1	1, 7, 33, 36, 40, 64, 78, 80, 86, 101, 103
Codfish Gadidae spp.	25 1		0.2±0 0.2-0.2 2				1.2±0.7 0.2-2.6 3	1, 16, 19, 67, 86
Crabs Mixed species	5,115±3,755 1,360-8,870 2				7.7±5.4 2.2-13.1 2			33, 44, 85, 114
Cusk *Brosme brosme*							2.5±2.0 0.5-4.5 2	16, 19
Cusk eels and brotulas Ophidiidae spp.							0.1 1	141

Table 1.—Continued.

	A (I.U.)	D (I.U.)	E (mg)	Choline (mg)	Ascorbic acid (mg)	Inositol (µg)	Biotin (µg)	References
	per 100 g							
Cuttlefishes Miscellaneous species					2.3±0.7 0.9-5.3 6			42, 79, 80, 97, 113, 147
Dace Cyprinidae spp.					1.0 1			87
Dolphins Coryphaenidae spp.	179±154 26-333 2							55, 80
Drums Sciaenidae spp.	199±155 31-508 3				10.2±3.9 2.5-14.1 3			4, 36, 57, 69, 85, 122
Eels, conger Congridae spp.					1.0 1			42
Eels, freshwater Anguillidae spp.	3,295±764 1,500-5,700 6	200 1			1.0±0.8 0.2-1.7 2			8, 30, 36, 61, 67, 80, 81, 96
Eels, snake Ophichthidae spp.	17 1							80
Eels, swamp Flutidae spp.	62±19 43-81 2							33, 80
Flounders, lefteye Bothidae spp.	335±182 114-695 3	43 1	140 1		1.0 1	7,519±609 6,015-8,520 4		48, 57, 62, 80, 130
Flounders, righteye Pleuronectidae spp.	48±13 34-73 3	60 1	0.4 1		1.0±1.0 0.0-2.0 2		1.2 1	1, 3, 48, 80, 83, 111
Goatfishes Mullidae spp.	104 1							33
Gobies Gobiidae spp.	891 1				0.5±0 0.5-0.5 2			6, 33, 42
Greenlings Hexagrammidae spp.	0 1							7
Grunts Pomadasyidae spp.	136 1							57
Gurnards, flying Dactylopteridae	59 1				0.0 1			27, 57
Haddock *Melanogrammus aeglefinus*	50 1				0.0 1		2.6±2.3 0.2-4.8 2	13, 19, 86, 138
Hake Gadidae spp.					1.0 1			35
Halibut Pleuronectidae spp.	440 1	44 1			0.0 1	8,350±5,407 1,400-19,000 3	8.1±1.5 6.6-9.5 2	9, 26, 83, 130
Herrings Clupeidae spp.	814±620 100-4,531 7	1,627 1			9.0±3.8 0.0-27.7 9	9,590 1		8, 35, 69, 78, 81, 83, 88, 89, 95, 122, 130
Jacks Carangidae spp.	125±53 72-177 2				3.3 1			33, 61
Lampreys Petromyzontidae spp.	30,060±6,584 9,060-44,300 6	260±140 120-400 2						36, 51, 148

Table 1.—Continued.

	A (I.U.)	D (I.U.)	E (mg)	Choline (mg)	Ascorbic acid (mg)	Inositol (μg)	Biotin (μg)	References
				per 100 g				
Lings *Molva* spp.							1.1±0.1 1.0-1.2 2	16
Lizardfishes Synodontidae spp.					3.0 1			80
Lobsters and crayfishes Mixed species	17 1				3.0±0.9 0.0-5.0 6		5.0±0.2 4.8-5.2 2	42, 78, 80, 83, 86, 87
Mackerels Scombridae spp.	107±40 0-711 17	1,036±273 143-2,000 6		11.1±4.4 2.5-29.2 6	3.0 1	8,060 1		5, 8, 15, 33, 48, 57, 58, 67, 80, 81, 89, 95, 130
Milkfishes Chanidae spp.	537±137 400-673 2							33, 80
Minnows Cyprinidae spp.	79 1							57
Mojarras Gerreidae spp.	62 1							33
Mussel Mytilidae spp.	1,226±1,193 33-2,418 2		0.5±0 0.4-0.6 3		4.1±1.4 1.1-9.0 6			15, 33, 36, 42, 53, 80
Octopuses Mixed species					0 1			83
Oysters Ostreidae spp.	273±36 170-366 5	40 1			10.7±5.4 0-38.1 7		41±31 10-72 2	33, 42, 46, 78, 80, 81, 83, 86, 95, 145
Perches Percidae spp.					1.2±0.0 1.1-1.2 2			87
Perches, climbing Anabantidae spp.	218 1							80
Plaice Pleuronectidae spp.							90 1	19
Pollock Gadidae spp.	32 1						3.7±2.4 1.3-6.1 2	3, 16
Pompanos Carangidae spp.	5.1 1				0.0 1			4, 27
Sardines and pilchards Clupeidae spp.	156±51 50-303 5	2,310±873 532-5,400 5						15, 33, 48, 103, 140
Sauries Scomberesocidae spp.	1,551±1,493 58-3,044 2				2.0 1			57, 80
Sawfish Pristidae spp.					0.0 1			83
Scad and mackerels Carangidae spp.	60±33 11-122 3		0.4 1		1.4±0.6 0.8-2.0 2			33, 35, 48, 57, 62, 80
Scallops Pectinidae spp.	0 1				3.0 1		0.3 1	78, 86
Sea chubs Kyphosidae spp.	19 1							57

Table 1.—Continued.

	A (I.U.)	D (I.U.)	E (mg)	Choline (mg)	Ascorbic acid (mg)	Inositol (µg)	Biotin (µg)	References
				per 100 g				
Sea cucumbers Mixed species					0.0 1			40
Sea robins Triglidae spp.					1.0 1			42
Shad Clupeidae spp.	138 1							33
Sharks, dogfish Squalidae spp.	797±211 114-1,600 8	15 1						8, 49
Sharks Miscellaneous species			270.0 1		0.0 1			27, 62
Sheathfishes Siluridae spp.	67 1							80
Shrimp and prawns Mixed species	108±35 20-297 8	150±0 150-150 2			1.5±0.6 0.0-3.0 5	542±319 4-2,400 7	1.0 1	5, 15, 27, 33, 36, 64, 76, 78, 80, 81, 83, 86, 98
Silversides Atherinidae spp.					1.0 1			83
Smelts Osmeridae spp.	96 1				1.4±1.4 0.0-2.8 2			57, 61
Snails Mixed species	83 1				15.0 1			80, 118
Snappers Lutjanidae spp.	187 1				0.3 1			65, 69
Snooks Centropomidae spp.					0.0 1			83
Soapies Leiognathidae spp.	33 1							80
Soles Pleuronectidae spp.	39 1							3
Spadefishes Ephippidae spp.	98 1							33
Squid Mixed species					4.9 1			113
Surfperches Embiotocidae spp.	62±17 45-79 2							57
Surgeonfishes Acanthuridae spp.					1.3 1			61
Therapons Theraponidae spp.	29 1							57
Threadfins Polynemidae spp.	172 1			8.0±0.0 8.0-8.0 2				10, 12, 69
Tilefishes Branchiostegidae spp.	17 1					6,350 1		80, 130

Table 1.—Continued.

	A (I.U.)	D (I.U.)	E (mg)	Choline (mg)	Ascorbic acid (mg)	Inositol (µg)	Biotin (µg)	References
	per 100 g							
Trout, salmon	173±49	360±107			7.1±1.9	19	3.7±1.4	7, 8, 9, 15, 19, 26,
Salmonidae spp.	3-600	30-1,200			1.3-9.0		0.9-5.3	46, 53, 55, 78, 81,
	17	12			4	1	3	86, 89, 95, 120
Trout, trout	41±28			87	1.1±1.1			31, 53, 83, 111
Salmonidae spp.	13-69				0.0-2.2			
	2			1	2			
Tuna	129±66	1,125±307		37	2.6±1.2		1.5	8, 15, 27, 33, 39,
Scombridae spp.	0-963	700-2,000			0.0-10.7			46, 57, 69, 78, 80,
	14	4		1	9		1	83, 86, 89, 95, 102
Turbon	233				2.0			80
Turbanidae spp.								
	1				1			
Turbots	39							3
Pleuronectidae spp.								
	1							
Whales	267							15
Physeter macrocephalus								
	1							
Whitings	54±54							33, 36
Sillaginidae spp.	0-107							
	2							
Wrasses	48							57
Labridae spp.								
	1							

[1]Average of the means.
[2]Range of the means.
[3]Number of mean values.

Table 2.—Composition of the edible portion of raw (fresh or frozen) crustaceans, finfish, and mollusks. IV. Vitamins: Thiamin, riboflavin, niacin, pyridoxine, folic acid, B_{12}, and pantothenic acid.

	Thiamin (µg)	Riboflavin (µg)	Niacin (mg)	Pyridoxine (µg)	Folic acid (µg)	B_{12} (µg)	Pantothenic acid (µg)	References
	per 100 g							
Abalone	[1]210±30	85±27	1.4±0.1	0.6		0.7	2,300±0	50, 64, 80, 81, 100, 151
Haliotidae spp.	[2]180-240	56-140	1.2-1.6				2,300-2,300	
	[3]2	3	3	1		1	2	
Amberjacks and yellowtails	115±33	84±17	8.3±8		3.5±0.3	4.2±1.4	598±3	2, 50, 64, 80, 85, 102
Seriola spp.	27-180	40-120	6.8-10		3.2-3.7	1.3-5.6	595-600	
	4	4	4		2	3	2	
Anchovies	19±7	104±24	3.1±0.4	181±27	12.3	6.3±0		44, 64, 66, 80, 84, 85,
Engraulidae spp.	8-37	79-152	2.3-3.5	144-260		6.3-6.3		93, 111, 116, 134, 153
	4	3	3	4	1	2		
Augar shells					21.1	12.6	60	80
Terebralia aulcatua								
					1	1	1	
Barracudas	92±21	70±11	4.1±0.6	350±101	11.9	1.4±0.4		64, 80, 82, 85, 88,
Sphyraenidae spp.	44-134	27-90	2.4-5.9	150-470		0.2-1.8		150, 153, 154
	4	5	5	3	1	4		
Basses, sea	79±13	114±33	2.4±0.4	300	8.8	5.0±2.4	7,530	3, 19, 27, 43, 44, 64,
Serranidae spp.	20-170	35-374	1.1-4.3			0.3-9.1		65, 80, 82, 85, 130
	14	13	12	1	1	4	1	
Basses, temperate	100	52	2.4					44
Percichthyidae spp.								
	1	1	1					
Bigeyes				400				155
Scombropidae spp.								
				1				
Billfishes	100	60	4.5					80
Isiophoridae spp.								
	1	1	1					

Table 2.—Continued.

	Thiamin (μg)	Riboflavin (μg)	Niacin (mg)	Pyridoxine (μg)	Folic acid (μg)	B_{12} (μg)	Pantothenic acid (μg)	References
	per 100 g							
Bluefishes Pomatomidae spp.	135±15 120-150 2	120±30 90-150 2	1.9±0 1.9-1.9 2					23, 82, 146
Bombay duck *Harpadon nochereus*	30±10 20-40 2	70±20 50-90 2	5.7±5.1 0.6-10.7 2	970 1				66, 80
Breams and porgies Sparidae spp.	77±18 10-190 15	96±21 20-250 15	5.4±6 1.5-7.8 12	460±0 460-460 2	1.6±1.2 0.4-4 3	1.8±0.4 0.1-2.8 7	213±8 205-220 2	2, 50, 64, 66, 85, 153
Burbot Gadidae spp.	388±27 306-455 6	141±1 140-142 2	1.6±0 1.6-1.6 2					43, 63, 71, 72, 139
Butterfishes Stromateidae spp.	163±1 163-164 2	223±109 90-550 4	4.8±1.2 2.6-8.1 4	450 1		2.3±0 2.3-2.3 2		29, 70, 80, 85, 116, 126
Butterflyfishes Chaetodontidae spp.	33±4 25-40 3	45±26 19-70 2	4.5±0.1 4.4-4.6 3					44, 64, 80, 109
Caesios Caesionidae spp.	24±4 20-28 2	24±4 20-27 2	3.8±0.6 3.2-4.3 2	190 1		2.3±0.8 1.5-3.1 2		50, 64, 80, 85
Carps Cyprinidae spp.	114±32 5-448 20	81±23 10-180 7	3.0±0.7 1.3-11 16	71±60 11-130 2	70±68 2.8-138 2	3.2±1.2 0.1-9 8	150 1	10, 11, 12, 29, 63, 71, 72, 80, 85, 109, 110, 111, 134, 136, 137, 149, 153, 154
Catfishes, airbreathing Claridae spp.	44±23 8-110 4	36±5 31-40 2	1.7±0.6 0.5-3.2 4		13.6±1.7 12.0-15.3 2	3.5±0.1 3.4-3.7 4	460 1	10, 11, 29, 36, 64, 80, 85, 109
Catfishes, freshwater Ictaluridae spp.	0 1		1.8±0.5 1.0-2.5 3		3.1±1.2 1.9-4.3 2	3.7±0.4 2.2-4.6 7	464±4 460-468 2	10, 11, 29, 50, 111, 116, 124, 135
Catfishes, sea Ariidae spp.	61±8 40-80 4	115±22 80-197 5	2.4±0.6 0.5-4.5 6	370 1	82.5±67.5 15-150 2	2.4±0.2 2.2-2.5 2	570 1	64, 109, 124, 138
Characins Characidae spp.	30±12 10-50 3	87±19 50-110 3	3.7±1.4 1.7-6.3 3			1.6 1		27, 65
Chimaeras Chimaeridae spp.					2.7 1		310 1	50
Cichlids Cichlidae spp.	30±0 30-30 2	85±35 50-120 2	2.3±0.8 1.5-3.1 2	320 1		2.9±0.2 2.7-3.0 2		82, 85
Clams, arkshels Arcidae spp.	2 1	200 1	1.5 1		17 1	13.6±6.4 7.2-20 2	790 1	50, 64, 151
Clams, freshwater Corbiculidae spp.					17 1	12.1 1	360 1	33, 50, 151
Clams, mactra Mactridae spp.	72±52 20-128 2	114±16 98-130 2				0.4±0.2 0.2-0.7 3		25, 151
Clams, razor Solenidae spp.	95±5 90-100 2	355±155 180-490 2	1.6±0.1 1.5-1.6 2			8.6 1		80, 81, 151
Clams, softshell Myacidae spp.	21±19 1-79 4	180±29 95-219 4	1.9±0.4 1.2-2.5 3	88±9 77-106 3		71.5±22.4 7.1-105.0 4	293±17 260-311 3	21, 59, 121, 125
Clams, Tellin Tellindae spp.	10 1	20 1	2.2 1	70 1	10.9 1			80
Clams Veneridae spp.	100±33 10-240 7	381±147 20-940 7	2.9±0.6 1.1-5.0 6			3.9±1.7 2.2-5.6 2		23, 44, 64, 85, 109, 125

Table 2.—Continued.

	Thiamin (μg)	Riboflavin (μg)	Niacin (mg)	Pyridoxine (μg)	Folic acid (μg)	B_{12} (μg)	Pantothenic acid (μg)	References
	— — — — — —	— — — — — —	— — — —	per 100 g	— — — —	— — — —	— — — —	
Clams	49±12	238±47	1.3±0.2	75±42	25.1±6.5	9.8±2.5	531±91	23, 45, 64, 75, 78, 80,
Miscellaneous species	2-139	12-780	0.2-2.3	0-350	2.7-58.0	0.2-62.3	440-622	86, 94, 100, 111, 123,
	14	16	9	8	7	34	2	125, 127, 142, 151
Codfishes	71±9	121±23	2.5±0.4	221±25	5.0±1.6	0.6±0.2	163±20	14, 16, 18, 19, 23, 36,
Gadidae spp.	18-150	11-325	0.2-6.7	170-288	1.8-6.7	0.1-2	96-400	43, 50, 59, 60, 73, 80,
	17	16	14	4	3	11	14	81, 86, 90, 97, 110,
								111, 112, 125, 134, 138,
								141, 144, 146, 155
Cornet						0		153
Fistulariidae spp.								
						1		
Crabs	85±20	382±280	2.5±0.2					23, 43, 44, 90
Mixed species	10-140	60-940	2.3-2.7					
	6	3	2					
Croakers	85±26	98±19	3.2±0.9	0.2		2.5		80, 81, 92
Sciaenidae spp.	40-160	60-150	1.7-5.5					
	4	4	4	1		1		
Cusk	38±6	303±160	2.7±0.2	304±30		1.0	261±44	16, 19, 23, 90, 138, 146
Brosme brosme	32-51	94-940	2.3-3.0	274-333			273-310	
	3	5	3	2		1	3	
Cusk eels and brotulas	175	35±3	1.8±0.4		2.0	0.6±0.3	115	65, 141
Ophidiidae spp.		32-37	1.4-2.2			0.3-0.9		
	1	2	2		1	2	1	
Cuttlefishes	96±59	480±430	2.1±0.8					70, 80, 113, 147
Miscellaneous species	9-210	50-910	1.2-2.9					
	3	2	2					
Dolphins	20	70	6.1			0.1		80, 153
Coryphaenidae spp.								
	1	1	1			1		
Dories				952		0		93, 153
Zeidae spp.								
				1		1		
Drepanes	29±2	111±30	3.2±0.4					64, 80
Drepanidae spp.	27-30	81-140	2.8-3.7					
	2	2	2					
Drums	63±14	131±46	3.1±0.7			2.4±1.5		2, 27, 59, 64, 65,
Sciaenidae spp.	20-130	31-530	0.5-8.9			0.2-5.3		70, 102, 124
	9	10	11			3		
Eels, arrowtooth				230			150	127
Dysommidae spp.								
				1			1	
Eels, conger	60	40±0	4.3±0.8			3	240	80, 138
Congridae spp.		40-40	3.5-5.0					
	1	2	2			1	1	
Eels, freshwater	191±31	335±51	2.3±0.5	254±15	11.6±1.6	1.0±0	141±6	19, 50, 59, 61, 80, 81,
Anguillidae spp.	144-280	190-520	1.4-3.5	230-300	10.0-13.1	1.0-1.0	125-150	84, 96, 111, 119, 134
	4	6	4	5	2	3	4	
Eels, moray	10	30	3.1			0.3±0.2		64, 153
Muraenidae spp.						0.1-0.4		
	1	1	1			2		
Eels, pike conger	60	90	2.7			0.2		80, 153
Muraenesocidae spp.								
	1	1	1			1		
Eels, snake	41±7	120	1.3±0.5			1.5±0.5		10, 12, 80, 85,
Ophichthidae spp.	30-53		0.5-2.3			1.0-2.6		109, 124, 149
	3	1	3			3		
Eels, spiny	60							109
Motacanthidae spp.								
	1							
Eels, swamp	85±45	135±85	2.2±0.4					33, 80
Flutidae spp.	40-130	50-220	1.8-2.5					
	2	2	2					
Featherbacks	85±35	55±15	3.3±2.6			3.4		29, 80, 135, 136, 137
Notopterus spp.	50-120	40-70	0.4-8.5					
	2	2	3			1		

Table 2.—Continued.

	Thiamin (μg)	Riboflavin (μg)	Niacin (mg)	Pyridoxine (μg)	Folic acid (μg)	B_{12} (μg)	Pantothenic acid (μg)	References
				per 100 g				
Flatheads Percophididae spp.	20±1 19-20 2	60±30 30-90 2	4.7±0.4 4.3-5.0 2				240 1	64, 80
Flounders, lefteye Bothidae spp.	85±15 70-100 2	73±27 46-100 2	5.3±0.4 5.0-5.7 2	130 1		1.3 1	900 1	65, 80, 153, 154
Flounders, righteye Pleuronectidae spp.	103±31 30-400 11	84±23 40-335 12	2.3±0.4 0.8-3.8 9	191±24 137-250 4	5±0 5-5 2	5.4±4.6 0.8-10 2	863±240 245-1,700 6	3, 19, 50, 59, 80, 81, 83, 84, 97, 110, 111, 115, 125, 134, 138, 146
Flyingfishes Exocoetidae spp.	17±7 4-26 3	56±10 40-80 4	3.9±0.6 3.0-5.6 4		2.8 1	1.0±0.4 0.3-1.3 3		64, 80, 85, 153
Gars Lepisosteidae spp.				900 1				134
Goatfishes Muliidae spp.	36±6 25-43 3	59±21 38-80 2	1.5±0.1 1.4-1.6 2	1.7 1				64, 80, 93, 109
Greenlings Hexagrammidae spp.	72±15 43-105 4	49±8 38-73 4		540 1	7.4±0 7.4-7.4 2	13.2±4.8 3.6-18.0 3	188±3 185-190 2	50, 67, 80, 111, 125, 140
Grunts Pomadasyidae spp.	77±23 18-200 7	226±126 32-900 7	4.2±0.9 2.0-8.6 7	200 1	7.0±3.5 3.5-10.5 2	0.4±0.3 0.1-0.7 2	270±0 270-270 2	27, 44, 50, 64, 65, 66, 80, 153, 154
Gurnards, flying Dactylopteridae spp.	85±75 10-160 2	75±5 70-80 2	2.8±0.7 2.1-3.4 2	480 1	1.8 1	0.3 1	225 1	27, 50, 80, 153, 154
Haddock *Melanogrammus aeglefinus*	39±5 9-100 19	69±11 12-210 24	3.6±0.1 2.4-4.3 20	231±16 122-300 11	0.8 1	1.3±0.1 0.5-3.5 19	145±17 49-380 20	18, 19, 20, 23, 43, 59, 60, 83, 86, 90, 111, 119, 127, 138, 141, 147
Hake Gadidae spp.	89±27 39-132 3	75±5 70-80 2	1.6±0.6 1.0-2.2 2	875 1				35, 44, 93, 119
Halibut Pleuronectidae spp.	83±11 40-180 13	80±11 44-185 15	7.5±1.0 2.8-14.2 11	400±15 347-430 5	2.6±0.3 2.0-2.9 3	0.8±0.1 0.7-1.0 6	303±50 111-595 11	7, 9, 19, 23, 25, 26, 50, 59, 77, 80, 83, 84, 86, 90, 110, 111, 125, 130, 134, 138, 141
Herring Clupeidae spp.	46±8 6-170 27	261±39 50-1,000 26	3.8±0.4 0.6-9.6 25	310±43 160-450 6	10.3±2.9 1.7-14.0 4	11.4±4.3 1.4-34.0 9	2,427±1,415 970-9,500 6	2, 9, 10, 11, 12, 14, 27, 29, 31, 36, 59, 64, 66, 67, 70, 73, 78, 80, 81, 82, 84, 95, 97, 110, 111, 117, 124, 125, 127, 138, 153, 154
Jacks Carangidae spp.	59±17 15-122 5	60±10 25-81 5	5.7±0.5 3.9-7.1 5	670 1		7.5±1.6 5.9-9.1 2		64, 80, 85
Lampreys Petromyzontidae spp.	339±256 46-850 3	520±93 427-612 2	4.7 1	195±25 170-220 2	25.5±1.7 23.6-29.0 3	4.1±0.3 3.8-4.4 2	425±145 280-570 2	50, 51, 80
Lings *Molva* spp.		80 1	2.5±0.2 2.3-2.7 2	265±44 221-309 2		1±0.5 0.5-1.9 3	320 1	10, 18, 97, 138
Lizardfishes Synodontidae spp.	92±12 80-104 2	39±11 28-50 2	2.9±0.5 2.4-3.4 2					64, 80
Lobsters and crayfishes Miscellaneous species	99±24 7-165 7	64±10 10-130 10	2.3±0.3 1.2-4.3 8	210 1	0.6±0 0.6-0.6 2	1.6±0.6 0.5-2.7 4	410±0 410-410 2	38, 59, 64, 78, 80, 83, 86, 90, 111, 138, 141, 149
Longarays Ambasidae spp.	11 1	39 1	1.5 1					64

Table 2.—Continued.

	Thiamin (μg)	Riboflavin (μg)	Niacin (mg)	Pyridoxine (μg)	Folic acid (μg)	B_{12} (μg)	Pantothenic acid (μg)	References
				per 100 g				
Mackerels Scombridae spp.	90±11 10-237 31	263±49 27-940 30	12.4±2.0 2.7-58.0 27	654±76 270-1,000 10		4.2±1.2 0.4-16.2 14	444±82 160-850 8	17, 23, 38, 43, 44, 50, 52, 54, 59, 64, 65, 66, 74, 80, 81, 85, 90, 101, 102, 105, 107, 109, 111, 112, 127
Milkfishes Chanidae spp.	57±44 13-100 2	77±23 54-100 2	6.1±0.3 5.8-6.4 2	420 1	15.9 1	3.4±0 3.4-3.4 2		64, 80, 85
Minnows Cyprinidae spp.	30 1	100 1	3.5 1	130 1				80, 154
Mojarras Gerreidae spp.	51±21 30-92 3	85±3 80-90 3	5.0±0.3 4.5-5.3 3	360 1	21.4 1	2.4±0.5 1.9-3.4 3		64, 65, 80, 85
Mussels Mytilidae spp.		150±30 120-180 2	1.6±0.4 1.2-2.0 2	98±92 6-190 2	41.8 1	10.2 1		1, 42, 80, 85
Needlefishes Belonidae spp.	4 1	39±2 37-40 2	0.9±0 0.9-0.9 2	655±85 570-740 2		1.9±0 1.9-1.9 2		64, 80, 85, 111
Ocean perches *Sebastes marinus*		110 1	2.0 1				360 1	138
Octopuses Mixed species	67±26 20-140 5	73±14 40-110 5	3.2±1.2 1.3-5.3 3	360 1				80, 83, 111, 125
Oysters *Ostreidae* spp.	153±11 9-300 36	188±15 16-340 29	1.8±0.2 0.7-7.1 34	166±25 30-320 18	84.4±77.8 3.7-240 3	17.2±2.6 11.5-33.0 9	365±22 184-530 22	1, 9, 22, 23, 34, 38, 40, 45, 59, 64, 78, 79, 80, 81, 83, 85, 91, 94, 95, 97, 100, 111, 115, 121, 127, 141, 142, 145, 151
Parrotfishes Scaridae spp.	29±24 5-53 2	57±6 50-70 3	1.4±0 1.4-1.5 3	180 1		0.6 1		64, 65, 80
Perches Percidae spp.	187±63 60-250 3	119±46 28-170 3	1.9±0.2 1.4-2.3 4					19, 28, 30, 63
Perches, climbing Anabantidae spp.	39±12 19-99 6	274±49 190-361 3	2.4±0.7 0.8-3.7 4	200 1	2.7±1.3 1.0-5.2 3			11, 12, 36, 64, 80, 109, 124
Pikes Esocidae spp.				135±17 115-150 2				111, 134
Plaice Pleuronectidae spp.	137±32 105-200 3	163±33 130-195 2	4.0 1	217±14 182-250 4		1.4±0.4 1.0-2.2 3	800±0 800-800 2	19, 84, 90, 111, 134
Pollock Gadidae spp.	82±18 45-160 6	122±18 80-200 7	2.6±0.6 1.6-2.9 4	238±60 60-473 6	65 1	2.1±0.5 1.0-3.5 5	274±41 140-380 5	3, 16, 18, 23, 45, 50, 59, 67, 80, 90, 111, 138, 146, 154
Pomfrets Bramidae spp.	120±70 50-190 2	190±110 80-300 2	0.6±0.2 0.4-0.8 2					66, 80
Pompanos Carangidae spp.	254±154 90-562 3	91±17 60-118 3	4.7±1.5 3.0-8.1 3					27, 44
Rays, stingray Dasyatidae spp.	50±10 36-80 4	44±5 30-50 4	3.5±0.6 2.5-4.6 4			0.1 1		64, 80, 153
Rockfishes Scorpaenidae spp.	96±18 29-153 7	150 1	3.0 1	143±88 55-230 2	4.7±4.3 0.4-9 2	1.0 1	177±92 80-360 3	50, 80, 111, 125, 154
Sandfishes Trichodontidae spp.	100 1	50 1			7.8±0 7.8-7.8 2		630±0 630-630 2	50, 80

Table 2.—Continued.

	Thiamin (μg)	Riboflavin (μg)	Niacin (mg)	Pyridoxine (μg)	Folic acid (μg)	B_{12} (μg)	Pantothenic acid (μg)	References
	— — — — — —	— — — — — —	— — —	per 100 g	— — — —	— — — —	— — — —	
Sardines and pilchards	19±8	107±38	6.3±1.0	424±231	2	5.6±2.3	1,030±30	8, 15, 23, 33, 36, 45, 48,
Clupeidae spp.	1-90	30-387	2.4-10	150-882		1.1-17.0	1,000-1,090	50, 64, 80, 82, 85, 93,
	10	9	9	3	1	7	3	103, 110, 111, 116, 140,
								153, 154
Sauries	50±1	112±11	6.0	660	6.4		850	50, 80, 99, 154
Scomberesocidae spp.	48-54	87-132						
	5	5	1	1	1		1	
Sawfishes	140	190	4.1					83
Pristidae spp.								
	1	1	1					
Scad and mackerel	139±19	141±13	6.0±1.3	406±98	4.3±2.4	5.3±1.4	350±0	19, 45, 50, 57, 64, 80,
Carangidae spp.	26-180	77-190	1.5-11.0	300-700	1.9-6.6	0.2-12.7	350-350	85, 101, 102, 103,
	8	7	7	4	2	11	2	140, 149, 153, 154
Scallops	85±45	83±18	1.3±0.1			8.9±7.6	138±6	78, 81, 94, 100,
Pectinidae spp.	40-130	65-100	1.2-1.4			1.2-24.0	132-143	111, 141
	2	2	2			3	2	
Scorpionfishes				55		7.6±4.4	80	67, 111
Scorpaenidae spp.						3.2-12.0		
				1		2	1	
Sculpins			3.2			6.1	100	50, 153
Cottidae spp.								
			1			1	1	
Sea cucumber	53±18	90±0	0.5			1.4±0.3		45, 80, 94, 125
Mixed species	35-70	90-90				0.5-2.0		
	2	2	1			4		
Sea robins	90							43
Triglidae spp.								
	1							
Shad	46±35	240-0	8.4				608	23, 33, 59, 64,
Clupeidae spp.	10-150	240-240						80, 111
	4	2	1				1	
Shark, dogfish	52±8	264±155	2.9±1.2		3.2	1.8±0	747±57	43, 50, 70, 80,
Squalidae spp.	40-66	80-573	1.0-5.2			1.8-1.8	690-860	90, 111, 138
	3	3	3		1	2	3	
Sharks, hammerhead	14	81	3.2					64
Sphyrnidae spp.								
	1	1	1					
Sharks, mackerel	105±25	91±10	9.5±2.5			3.0±0.4	330	2, 138
Lamnidae spp.	80-130	81-100	7.0-12.1			2.6-3.4		
	2	2	2			2	1	
Sharks, sand tiger	20	30	4.4					44
Odontaspididae spp.								
	1	1	1					
Sharks	40±16	57±15	4.0±0.9			0.4±0.2		27, 64, 65, 80,
Miscellaneous species	5-110	19-110	0.9-6.6			0-0.7		102, 116
	6	6	6			3		
Sheathfishes	10	40	1.4					80
Siluridae spp.								
	1	1	1					
Shiners						1.4		10
Cyprinidae spp.								
						1		
Shrimp and prawns	41±6	76±11	2.7±0.3	66±13	5.2±2.2	3.8±1.0	278±16	27, 36, 38, 64, 78, 80,
Mixed species	10-143	13-190	0.7-4.9	16-125	3.0-7.4	0.9-8.1	165-372	81, 83, 84, 85, 86, 90,
	28	26	17	10	2	7	15	98, 108, 111, 125, 127,
								134, 138, 141, 143, 149
Siganids	203±43	129±2	4.8±0.4	140		0.1		64, 80, 153
Seganoidae spp.	160-245	127-130	4.4-5.1					
	2	2	2	1		1		
Silversides	88±71	65±15	2.9±1.6					43, 80, 83
Atherinidae spp.	10-230	50-80	1.3-4.5					
	3	2	2					

Table 2.—Continued.

	Thiamin (μg)	Riboflavin (μg)	Niacin (mg)	Pyridoxine (μg)	Folic acid (μg)	B_{12} (μg)	Pantothenic acid (μg)	References
	per 100 g							
Sleepers Eleotridae spp.	26 1							109
Smelts Osmeridae spp.	54±26 10-130 4	143±33 43-360 8	1.9±0.4 1.3-3.0 4	120 1	5.0±1.3 3.7-6.3 2	1.8±1.6 0.2-3.4 2	919±281 638-1,200 2	15, 50, 59, 63, 80, 86, 125, 141, 153, 154
Snails Mixed species	56±54 2-110 2	169±111 58-280 2	1.5±0.2 1.3-1.6 2	120 1	31.8 1	26.7±7.1 9.0-77.0 10		64, 80, 85, 151
Snappers Lutjanidae spp.	88±18 46-170 6	81±17 38-131 5	3.6±0.6 2.5-5.2 5	100±100 0-200 2				43, 44, 64, 65, 80, 83
Snooks Centropomidae spp.	134±47 48-350 8	150±59 48-440 7	1.4±0.4 0.7-3.1 8		65.0 1	3.4±0 3.4-3.4 2		10, 11, 12, 29, 36, 44, 64, 66, 80, 83
Soapies Leiognathidae spp.	43±16 13-70 4	39.3±0.8 37-40 4	2.1±0.1 1.9-2.5 4	170 1	23.6 1	3.6±0 3.6-3.6 2		64, 80, 85
Soles Pleuronectidae spp.	62±5 38-88 10	48±2 37-57 7	1.1 1	1,045 1	3.0±0.1 2.9-3.1 2	0.1 1	420±197 155-805 3	3, 9, 50, 93, 111, 119, 125, 153
Soles Soleidae spp.	72 1							15
Spadefishes Ephippidae spp.	66±46 20-158 3	157±7 150-170 3	5.2±0.1 5.0-5.3 3			2.6±0 2.6-2.6 2		33, 64, 65, 80
Squid Mixed species	43±19 8-150 7	218±104 50-836 7	2.6±0.5 1.2-4.7 7	623±360 70-1,300 3	12.5 1	4.5±2.9 1.3-13.0 4	680 1	45, 54, 65, 80, 81, 93, 98, 100, 113
Suckers Catostomidae spp.	15±11 4-36 3	50 1	1.3±0.1 1.1-2.0 7				464 1	19, 44, 63, 71, 72, 111
Sunfishes Centrarchidae spp.			0.5 1				512 1	111, 124
Surgeonfishes Acanthuridae spp.	29±2 27-30 2	28±2 26-30 2	3.8±0 3.8-3.8 2		10 1	1.1±0.5 0.6-1.6 2	320 1	64, 80, 153
Tarpons Elopidae spp.	54±21 16-90 4	52±5 39-60 4	3.6±0.7 1.6-5.1 5					29, 64, 80
Therapons Theraponidae spp.	23±2.5 20-28 3	71±5 63-81 3		600 1		4.9±2.2 2.7-9.2 3		57, 64, 80, 85
Threadfins Polynemidae spp.	25±5 19-40 4	93±26 50-160 4	2.6±0.6 1.5-4.6 5		70 1			11, 64, 66, 79, 80
Tilefishes Branchiostegidae spp.	80 1	111 1	2.8 1	45 1				80, 154
Tonguefishes Cynoglossidae spp.	50 1	150 1	3.3 1					80
Trout, salmon Salmonidae spp.	130±15 30-348 23	143±13 46-231 26	7.2±0.2 5.6-8.8 15	745±54 590-975 6	3.9±0.4 2.2-4.8 6	1.7±0.5 0.1-5.0 13	988±144 490-2,080 15	15, 19, 23, 24, 25, 26, 43, 47, 53, 55, 59, 73, 78, 80, 81, 84, 95, 97, 101, 104, 106, 111, 120, 125, 127, 132, 134, 138, 141, 144, 146, 149, 153
Trout, trout Salmonidae spp.	80±9 10-140 12	109±17 10-210 15	4.2±0.6 2.5-7.8 9	690±0 690-690 2		3.3±0.8 1.0-5.0 6	1,843±77 1,630-2,000 5	19, 38, 44, 59, 61, 80, 83, 111, 125, 138, 152, 153

Table 2.—Continued.

	Thiamin (μg)	Riboflavin (μg)	Niacin (mg)	Pyridoxine (μg)	Folic acid (μg)	B_{12} (μg)	Pantothenic acid (μg)	References
				per 100 g				
Trout, whitefish Salmonidae spp.	88±5 27-126 26	120±0 120-120 3	2.8±0.2 0.6-4.6 15					19, 43, 63, 71, 72
Tunas Scombridae spp.	120±21 10-434 22	164±31 13-660 28	9.7±1.1 0-23.4 21	647±72 190-920 10	2.1±0.7 0.6-3.2 4	6.2±2.5 0.2-47.0 19	917±313 186-3,280 9	2, 15, 17, 18, 27, 45, 56, 64, 70, 74, 80, 82, 84, 89, 95, 105, 110, 127, 131, 134, 138, 141, 146, 147, 149, 153, 154
Turbons Turbanidae spp.	60 1	60 1	3.0 1	1,700 1	7.3±0 7.3-7.3 2	0.3 1	305±45 260-350 2	45, 50, 80
Turbots Pleuronectidae spp.	46±14 18-60 3	86±28 40-137 3	1.1±0.4 0.6-1.5 2			1.3±0.3 1.0-1.5 2	250±0 250-250 3	3, 15, 111, 119, 127, 138
Whiting Sillaginidae spp.	36±15 21-50 2	80±20 60-100 2	6.1±0.7 5.4-6.9 2					64, 80
Wolffishes Anarhichadidae spp.				350 1		2.0 1	570 1	111
Wrasses Labridae spp.				80 1		3.0±2.3 0.7-5.3 2		42, 57, 153, 154

[1]Average of the means.
[2]Range of the means.
[3]Number of mean values.

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MFR PAPER 1356

Review of Oxygen Depletion and Associated Mass Mortalities of Shellfish in the Middle Atlantic Bight in 1976

FRANK W. STEIMLE and CARL J. SINDERMANN

ABSTRACT–In summer and autumn of 1976, mass mortalities of shellfish occurred in a 165-km long corridor of severe oxygen depletion paralleling the New Jersey coast from 5 to 85 km from shore. Mortalities of surf clams, Spisula solidissima, *the most severely affected species, were estimated in excess of 140,000 t. Alteration of normal migration patterns of lobsters and several species of finfish was also noted. A series of anomalous meteorological and hydrological events (particularly early warming of surface waters resulting in early thermocline development, and a massive shelf-wide phytoplankton bloom) superimposed on an already stressed coastal area, was considered to be responsible. The occurrence is particularly significant because the continental shelf of the Middle Atlantic Bight, from Cape Cod to Cape Hatteras on the east coast of the United States, contains the largest known stocks of ocean shellfish of any comparable coastal area of North America.*

INTRODUCTION

Mass mortalities in the sea are relatively common events and always attract the interest of the scientific community as well as the public. This interest may be based on a concern for the loss of a fishery resource, or the nuisance or health problems created by the decaying animals. Very often it is difficult to identify the cause of mass mortalities because most investigations begin after the fact, so the conditions which lead to the mortalities may have been altered or dissipated by the time studies begin. The majority of mass mortalities are very localized, often confined to a particular bay or estuary, but a few can be widespread, sometimes affecting hundreds of square kilometers of ocean.

The recognized causes of the mass mortalities have been physical (vulcanism, rapid or extreme temperature changes, storms, seaquakes, and strandings), chemical (extreme salinity or pH changes, oxygen depletion, toxic chemicals, and hydrogen sulfide formation), biological (disease and toxic or massive algal blooms), or combinations of the above. Many mass mortalities have been reported in the scientific literature since the 19th century and fossil evidence of mass mortalities exists. Brongersma-Sanders (1957) has compiled the most comprehensive review to date; other reviews include those of Sinderman (1970, 1976).

An environmental event of heroic proportions, leading to mass mortalities of many marine species in a 12,000 km² area of the continental shelf off the Middle Atlantic coast of the United States occurred during July through October 1976. Investigators were able to detect conditions that were lethal to marine life; these conditions were extreme oxygen depletion and hydrogen sulfide formation in bottom waters. First reports of this developing environmental problem reached the scientific community during the weekend of 4 July. Sport divers, lobstermen, and trawler fishermen had observed and reported dead and dying marine organisms, both fish and invertebrates, on fishing reefs and wrecks, and on fishing grounds, off the north-central New Jersey coast, south of New York City. Within a few weeks the mortalities were reported in areas extending southward some 85 km and well out on the continental shelf.

A series of survey cruises was initiated by the National Marine Fisheries Service's Northeast Fisheries Center, Sandy Hook, N.J., to examine the extent of the problem, to assess the damage, and investigate possible causes. Oxygen deficient bottom water, sometimes with zero dissolved oxygen levels, was found for a north-south distance of 165 km in a zone or corridor from 5 to 85 km off the New Jersey coast.

In the central part of this zone, oxygen values were zero, and hydrogen sulfide was detected below the thermocline. Oxygen depletion persisted until October, when lower surface temperatures and mixing, after disappearance of the thermocline, gradually reoxygenated the bottom water.

Mortalities of fish, lobsters, molluscan shellfish, and other benthic invertebrates were observed. The sedentary forms, surf clams, ocean quahogs, and sea scallops, suffered the greatest mortalities. From almost continuous surveys, it was estimated that 69 percent of the surf clam population off the New Jersey coast, representing some 143,000 t of meats, had been destroyed by October, with significant but lesser mortalities of ocean quahogs and sea scallops. Lobster catches were reduced by 30 percent during the period. The New Jersey coast was declared a resource disaster area in November by the

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Federal government because of this event.

The problem was complicated by the public's premature conclusion that ocean disposal of pollutants, particularly sewage sludge dumping (over 5 million tons were dumped in 1976), 20 km from the coast, was responsible for this oxygen depletion situation and associated mortalities. Concern was also expressed that this catastrophic event might be repeated, possibly even annually.

The extent and duration of the problem and tremendous impacts on the fisheries and businesses in the area stimulated a massive investigation effort by State, Federal, and private groups or agencies. An interagency group was created to coordinate research efforts and finally to draw all available data together by holding a series of workshops, during November 1976. The results of these workshops, which are for the most part preliminary analyses of available data were published as an interim report (National Marine Fisheries Service, 1977).

From these workshops a large amount of data has been assembled and a causal hypothesis developed, centering on a combination of unique atmospheric, hydrographic, and biological events, which occurred in a coastal area already stressed by human organic loading.

The major environmental disturbances of 1976 in the Middle Atlantic Bight may prove to be one of the best-documented examples that we have of a mass mortality in the sea and its short- and long-term impacts on resource and foodchain species. Scientific studies are continuing, especially since the possibility of repetition of the event, at some level of intensity, exists for future years.

This paper is a review of the situation based partially on the workshop reports and includes subsequent data and assessments.

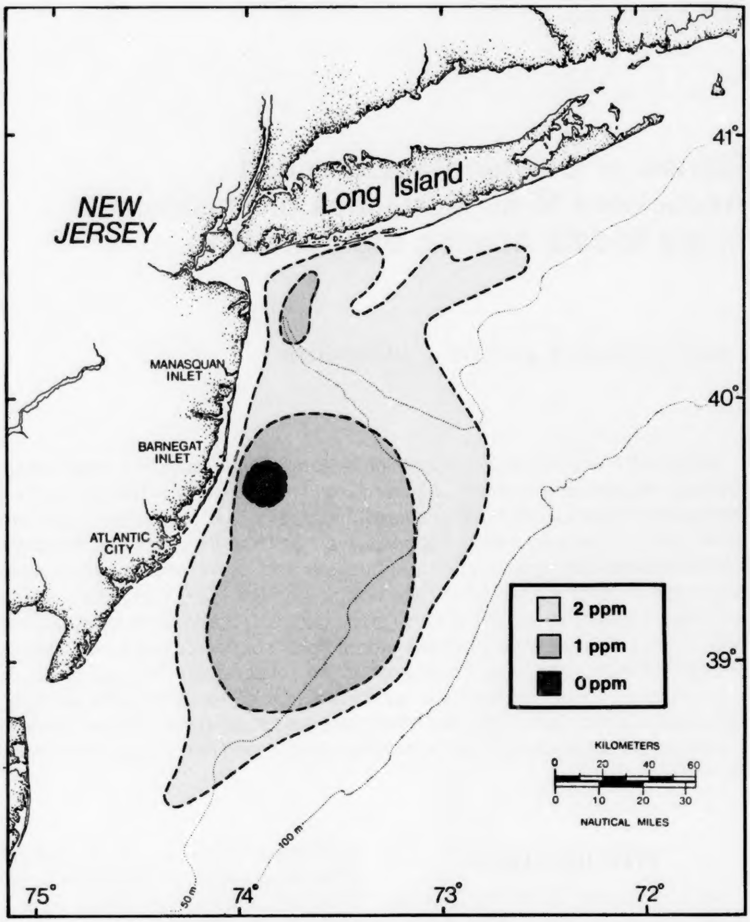

Figure 1.—The bottom oxygen levels in New York Bight at period of greatest distribution, late September 1976.

EXTENT OF OXYGEN DEPLETION

One major aspect of the 1976 investigation was the monitoring of the levels and distribution of dissolved oxygen in the sub-thermocline bottom waters. Sampling in mid-July found depressed dissolved oxygen (D.O.) values, some below the level of detection by standard Winkler procedure, in an area 3-35 km off Barnegat Inlet, 115 km south of New York City (Fig. 1). Values of less than 2 ppm were found between Long Branch to north of Atlantic City, a coastal distance of 105 km. Trawl surveys collected dead epibenthic invertebrates and stressed surf clams in this zone and noted an absence of the normal finfish population known to inhabit the area in the summer.

By early August, prior to Hurricane Belle, which passed the New Jersey coast on 10 August, the anoxic area had moved or expanded southward, with the center of the oxygen-depleted area being found between Barnegat Inlet and Atlantic City, a distance of 70 km on the central New Jersey coast. Extremely high levels of hydrogen sulfide (to 1.76 mg/l) were also detected near the center of the depleted area. The hydrogen sulfide was present up to 15 m from the bottom (35 m deep), but not above the thermocline (Draxler and Byrne, 1977).

Hydrogen sulfide was also evident in an apparent upwelling of anoxic bottom water along very restricted portions of the immediate shoreline in central New Jersey. Hundreds of fish of several species, including sharks, were trapped along the beach and killed. A period of strong westerly winds, pushing the inshore surface waters offshore, was thought responsible.

The hurricane, from which many had hoped for relief, did not significantly alter the situation. Immediately after its passage, resurveys of stations off Atlantic City which had been surveyed just prior to the storm found some possible coastal mixing or an offshore shift, resulting in the less than 2 ppm D.O. area moving from 3 km off the coast to 25 km offshore as the only apparent effect. This was only temporary, because a second resurvey, 5 days later, indicated the anoxic water mass had resumed most of its prehurricane distribution, with further movement or expansion south-southeast (Steimle, 1977a).

By mid-September, the anoxic area (defined here as the area where bottom water D.O. values were less than 2 ppm), reached its greatest known distribution, covering approximately half the New York Bight, including a tongue off Long Island, and extending southward to the Maryland State border (Fig. 1).

By the first week in October, surveys found that the thermocline was apparently decaying because bottom D.O. concentrations inshore, out from the coast to 40 km, were increasing to nonhazardous levels. By early November, no trace of oxygen depletion was evident and the 1976 oxygen depletion phenomenon had evidently ended.

RELATED METEOROLOGICAL AND HYDROLOGICAL EVENTS

Data from intensive field operations in the Middle Atlantic Bight during the critical period, combined with meteorological observations, were examined in the interagency workshops. It was the general conclusion of the workshops (National Marine Fisheries Service, 1977) that large-scale meteorological and oceanographic phenomena were involved in production of the anoxic zone which resulted in mortalities. The hypothesis which was developed focused on a somewhat unique combination of anomalous environmental events superimposed on a marginal coastal area, which has been made eutrophic by man's input of organic material.

Meteorological events included: 1) High February-March temperatures with peak river runoff in February instead of April; 2) reduction of cyclonic storm activity during the summer to less than half the 25-year average; and 3) a period of 4-6 weeks in June-July with persistent south or southwest winds (Diaz, 1976).

Physical oceanographic events included: 1) Early (February-March) warming of surface waters and development of the thermocline (thermal stratification usually begins in April and reaches a maximum in August); and 2) early onset of decline in subsurface dissolved oxygen values (January rather than March). Bottom water D.O. values in May 1976 off New Jersey were as low as they usually are in July (Armstrong, 1977).

Biological oceanographic events included: 1) A massive bloom of the dinoflagellate *Ceratium tripos* over much of the Middle Atlantic Bight, but particularly concentrated in the New York Bight. The bloom began in February, persisted at least until July, and was concentrated at and just below the thermocline (Malone, 1977).

Since the Middle Atlantic Bight has been the focus of intensive research by elements of the National Oceanic and Atmospheric Administration for several years, a number of earlier investigations had been conducted. This historical data base enabled comparison with conditions which existed in previous years. Based on such comparisons, an explanation of the events of 1976 could be summarized in several steps: 1) Oxygen demand from a declining phytoplankton bloom was superimposed on a shallow shelf area (New Jersey coast) already characterized by reduced dissolved oxygen in an average summer; 2) this organically rich oxygen demanding water was sealed off early in spring by the early onset of a thermocline; 3) water mass movement was reduced to a minimal southward flow of bottom water; and 4) cyclonic storm activity during the entire period was abnormally low. With these factors, the ingredients of disaster to marine animals were present.

FISH AND SHELLFISH STOCKS OF THE MIDDLE ATLANTIC BIGHT

Fish and shellfish populations of the Middle Atlantic Bight are abundant and important to the nation's economy. Oceanic species of bivalve mollusks, particularly surf clams, ocean quahogs, (*Arctica islandica*), and scallops (*Placopecten magellanicus*) are more numerous here than in any comparable coastal area in the United States. Surf clams harvested from the Middle Atlantic Bight constitute over 50 percent of total landed weight of molluscan shellfish in the United States; the fishery for ocean quahogs is expanding rapidly, and populations of sea scallops are fished regularly in deeper waters of the Bight.

The National Marine Fisheries Service has conducted surveys of surf clam, ocean quahog, and scallop distribution and abundance in the Middle Atlantic Bight for a number of years. The most recent surveys for surf clams, ocean quahogs, and sea scallops were in April 1976. Total estimated biomass of offshore surf clams in the Bight was 875,000 t of meats, with the New Jersey sector containing 207,000 t. Total estimated biomass of ocean quahogs in the Bight was 2,450,000 t of meats, with the New Jersey sector containing 818,000 t (Ropes and Chang, 1977). Biomass estimates for sea scallops in the Bight are not available, but much of the stocks are composed at present of a single strong year class (1972). Scallops occupy about 11,500 km^2 of the shelf off New Jersey (MacKenzie, 1977).

Finfish species presently of significance in the Middle Atlantic Bight include scup (*Stenotomus chrysops*), summer flounder (*Paralichthys dentatus*), bluefish (*Pomatomus saltatrix*),

striped bass (*Morone saxatilis*), mackerel (*Scomber scombrus*), black sea bass (*Centropristis striata*), and weakfish (*Cynoscion regalis*). A number of these species are taken by recreational as well as commercial fishermen, often with the recreational catch predominating. Some of the species exist as year-round local populations, while others, such as summer flounder and bluefish, migrate vertically to and from the coast, or laterally north and south through the Bight. A few species (mackerel and silver hake, *Merluccius bilinearis*) have until recently been exploited heavily by foreign distant-water fleets. Most of the Middle Atlantic finfish stocks of interest to U.S. fishermen (other than mackerel) have not declined drastically in recent decades, and increased landings characterize species such as bluefish, striped bass, and weakfish since 1970 (McHugh, 1977).

The National Marine Fisheries Service (and its predecessor agencies) has also conducted trawling surveys for demersal fish in the Middle Atlantic Bight for the past decade to provide a basis for continuing stock assessment. Additionally, recreational fish surveys have been carried out during the past 3 years. Landing figures for important recreational and commercial species are summarized in Figure 2.

EFFECTS ON SHELLFISH AND OTHER BENTHIC POPULATIONS

Begining in late July 1976, assessment of the impact of the anoxic event on the surf clam stocks began. Signs of stressed surf clams were noted by divers as early as the weekend of 4 July. These were clams that were not embedded in the sediment but were lying free on the surface. Several later trawl surveys also found live, but gaping clams. The first specific surf clam dredging survey was completed by the end of July. Mortalities ranging between 0 and 56 percent were found in a restricted area off Barnegat Inlet. A second survey, in early August, found an average mortality of 10 percent in clam stocks in

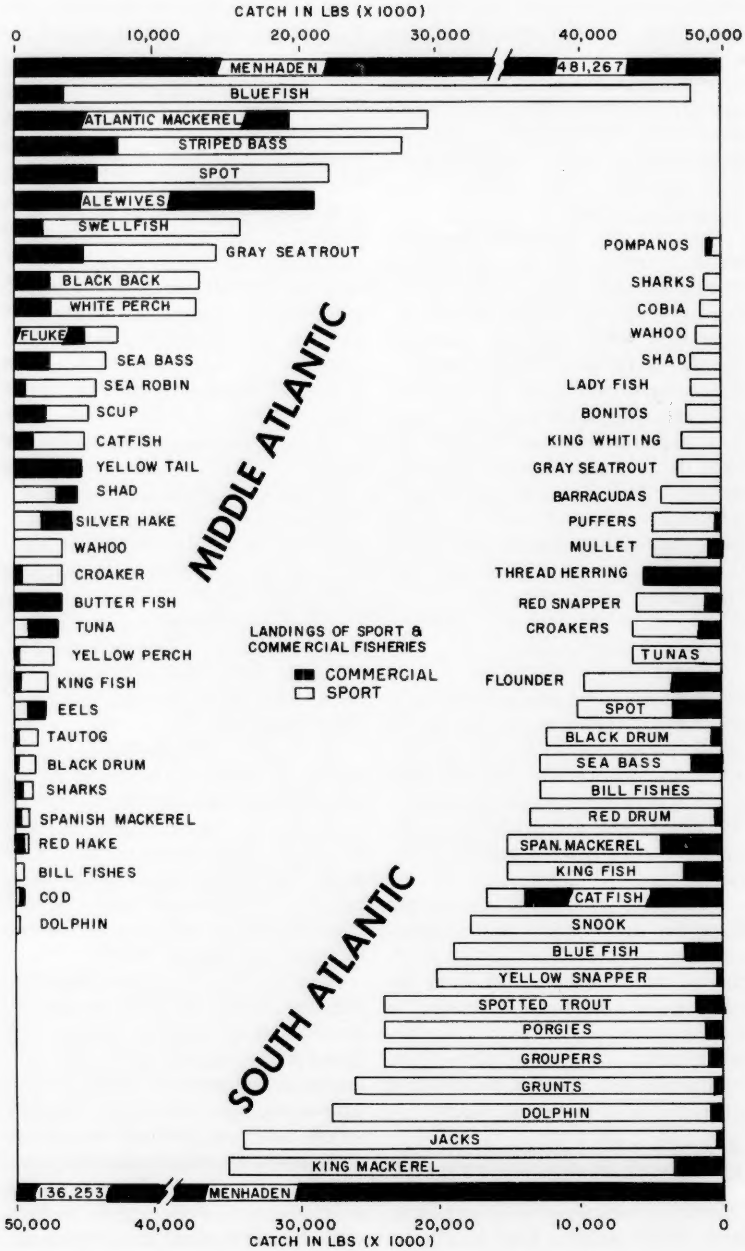

Figure 2.—Landings of recreational and commercial species in the Middle Atlantic Bight in 1970 (National Marine Fisheries Service, 1973).

the impacted area. The normal mortality is 2 percent (Ropes and Chang, 1977).

Subsequent expanded resurveys in September and October found that the average mortality had risen to 100 percent at some stations in a 12,000 km^2 sector off New Jersey. It was estimated that this represented, by October 1976, a loss of 143,000 t of surf clam meats, or about 69 percent of the offshore surf clam stocks of New Jersey, and 16 percent of the estimated total Middle Atlantic Bight population of the species (Fig. 3). Of the coastal surf clam stocks (those within 5 km of shore) an estimated 1,700 t were killed in an area south of Beach Haven—representing about 5 percent of the total inshore coastal population (Ropes and Chang, 1977). Because July is the normal spawning season for surf clams, the impact on future stocks may also be severe.

Mortalities were observed also in New Jersey's ocean quahog population, an increasingly valuable resource species, which is usually found in deeper water than the surf clam. In early August, mortalities for this species were less than 1 percent. Mortalities increased in September to almost 8 percent, with a high of 40 percent at some individual stations. The loss to New Jersey stocks of ocean quahogs was about 6,600 t, or less than 1 percent of the stocks in that sector of the coast (Fig. 4) (Ropes and Chang, 1977).

Sea scallops, which also occur in deeper water than surf clams, were affected by the anoxic event. Scallops occupy an area of 11,500 km^2 off the New Jersey coast; of this, 4,300 km^2 were within the anoxic zone, and an estimated 10 percent of the population was killed in a zone 35-55 m deep (Fig. 5) (MacKenzie, 1977).

The lobster, *Homarus americanus*, industry off New Jersey suffered. Some of the inshore stocks were killed, and the annual shoreward migration of offshore stocks was interrupted. During the months of June through September, normally the most productive months of the year, landings declined an average 30 percent compared with the same period in 1975. The inshore pot fishery, which operates within 20 km of shore, was most severely affected. Lobstermen stated that few offshore migrants entered the fishery in 1976 (Halgren, 1977).

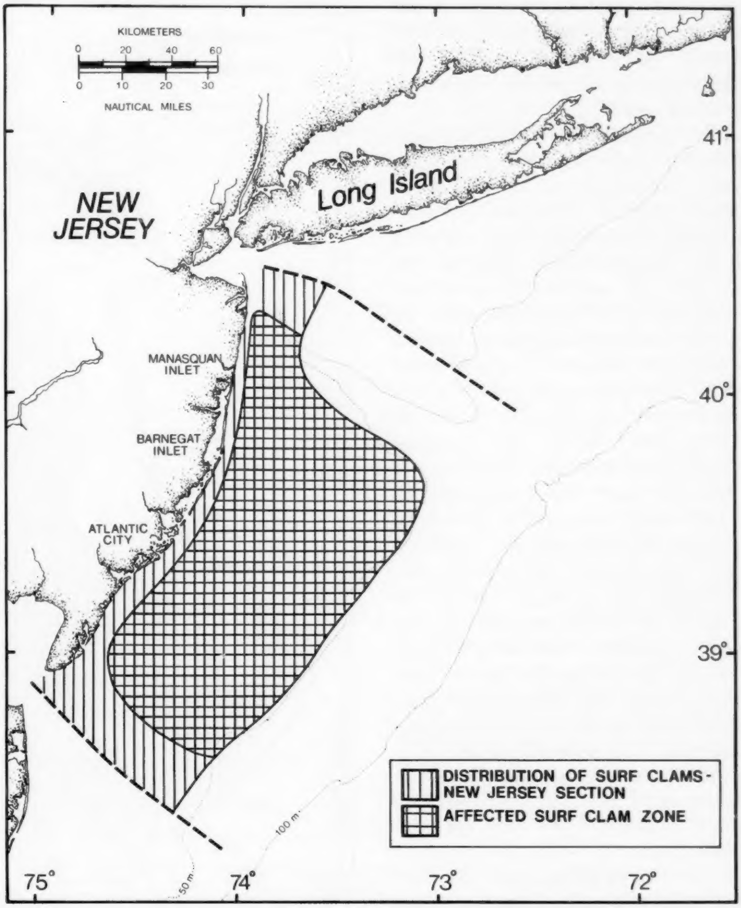

Figure 3.—Distribution of surf clam mortalities in New York Bight.

Other benthic populations were affected by the anoxic water. Effects on the benthic infauna were most noticeable in the H_2S zone, with reduction in numbers of species and numbers of individuals. Species to species variability in survival was noted, with a number of polychaetes and sea anemones quite resistant to prevailing extreme environmental conditions. Among the benthic megafaunal species affected were rock crabs (*Cancer irroratus*, *C. borealis*), mud shrimp (*Axius serratus*), mantis shrimp (*Platysquilla enodus*), starfish (*Asteria* sp.), moon snail (*Lunatia heros*), sea cucumbers, (*Thyone* sp.), and sand dollars (*Echinarachnius parma*). Many of the more mobile crustaceans were able to avoid the developing anoxia, but not all of them (Radosh et al., 1977; Steimle, 1977b).

Oxygen depletion in bottom waters may prove to be a common feature in localized areas where ocean shellfish occur. Drastic changes in abundance of species such as the surf clam, which has been observed previously, may in some instances be caused by anoxia. It may

be too that the presence of anoxic bottom waters may influence post-larval settling and survival of clams, even eliminating set of a particular year class in certain areas.

The survival of marine invertebrates, including shellfish, in oxygen-depleted waters, and in the presence of hydrogen sulfide, has been examined, and additional experiments are being conducted by the National Marine Fisheries Service. Earlier studies (Theede et al., 1969; Davis, 1975) and preliminary results of current studies indicate survival of clams for periods of several weeks in water which approaches zero D.O., but shorter survival in hydrogen sulfide environments. These experimental findings agree with field observations in 1976. Surf clams began showing signs of stress early in July, but mortalities were not reported until the middle of July. The extended period of anoxia, combined with hydrogen sulfide, resulted in 100 percent mortality by October at stations in the most severely affected zone along the central New Jersey coast, but lesser mortality in peripheral areas of less severe oxygen depletion. The majority of the mortalities occurred in July and August, as evidenced by mostly clapper (meatless paired shells) bivalves collected after September.

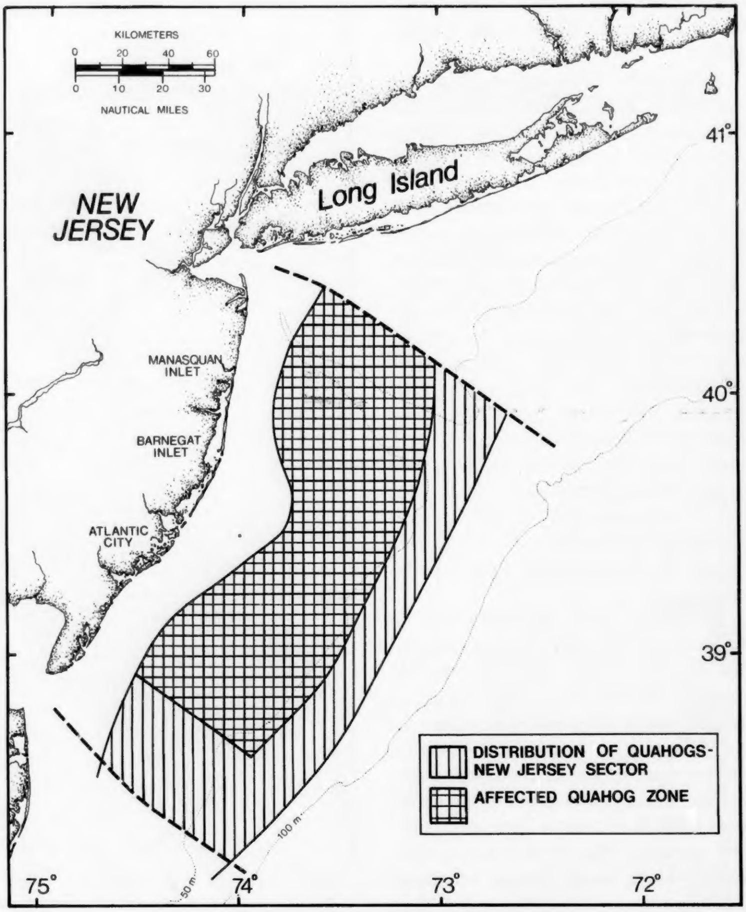

Figure 4.—Distribution of ocean quahog mortalities in New York Bight.

EFFECTS ON FISH POPULATIONS

Even though some mortalities of finfish were reported early in the event, it seems that the principal effect of oxygen depleted waters below the thermocline was to modify the normal movements and migrations of a number of species. Summer flounder were crowded within a narrow coastal zone or in estuaries, where they were readily available in large numbers to fishermen. Bluefish, which normally migrate northward through the area in summer, were shown by results of tagging studies to have reversed their direction, and moved southward (Freeman and Turner, 1977a, 1977b; Festa, 1977).

Demersal species apparently abandoned the oxygen-minimum and hydrogen sulfide area completely. Several trawling surveys through the area in August, September, and October disclosed almost complete absence of any demersal fish species—an unusual event when compared with similar trawling surveys conducted in the Middle Atlantic Bight since 1968. Very few dead fish were brought up in the nets during the 1976 surveys, although dead invertebrates were common (Azarovitz et al., 1977).

There is genuine concern, however, that survival of the 1976 year class of demersal spawning fish may have been severely affected in the anoxic zone (Smith, pers. commun.[1]).

[1]Smith, W. National Marine Fisheries Service, NOAA, Highlands, N.J. Pers. commun.

DISCUSSION

There are, of course, other coastal areas in the world where extreme oxygen depletion in bottom waters is a frequent, sometimes even an annual, event.

Marine fish kills related to oxygen depletion and hydrogen sulfide buildup have been reported in warm shallow estuaries (May, 1973) and in areas of upwelling and mass production of plankton, e.g., off South America and Africa (Brongersma-Sanders, 1957; Theede et al., 1969).

A coastal upwelling region famous for its low oxygen, hydrogen sulfide production, and periodic mortalities, is

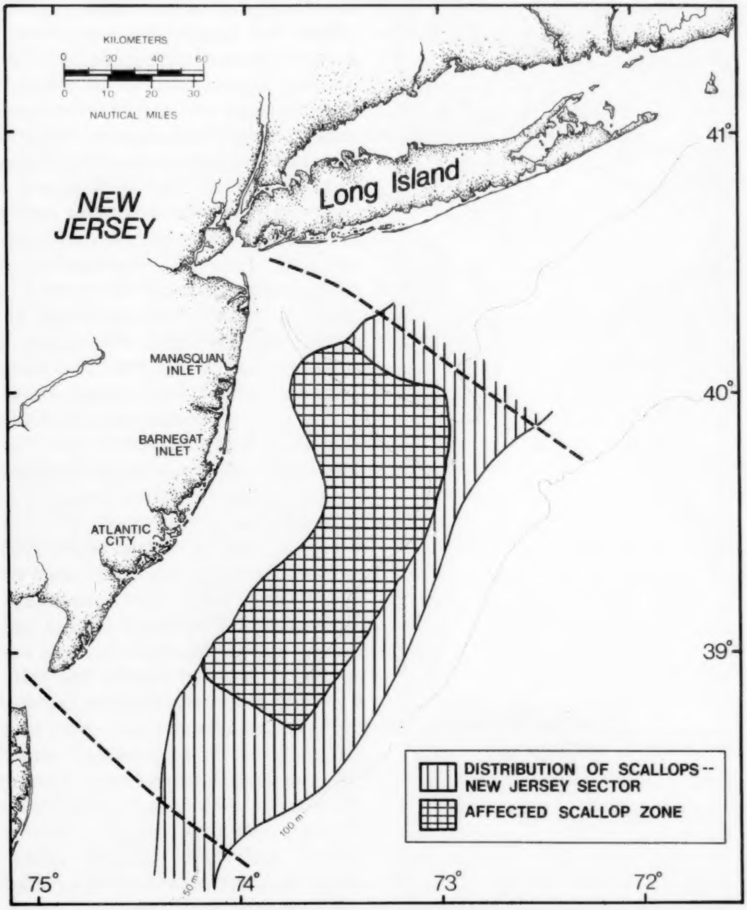

Figure 5.—Distribution of scallop mortalities in New York Bight.

off the southwest coast of Africa, in and near Walvis Bay. Scientific records of mortalities, summarized by Brongersma-Sanders (1947, 1957), extend back to 1837. Dead and dying fish, cephalopods, and bivalves have been observed with great frequency in December and January in the sea and on the beaches between lat. 21°S and 25°S. The sea bottom of the region is highly organic, with high H_2S content and anoxic bottom waters. Mass mortalities of fish are more severe in some years than in others, and are often preceded by red to brown discoloration of the sea from algal blooms. The anoxic area involved is approximately 14,000 km^2, but, interestingly, there is a narrow coastal strip about 5 km wide, extending to a depth of 40 m, where sea life is normal and hydrogen sulfide does not occur (Copenhagen, 1953). Similar mass mortalities of marine animals in a zone of upwelling have been reported by Falke (1950) from Concepcion Bay, Chile.

Mass mortalities, particularly of benthic fauna, have occurred in the deeper basins of the Baltic, where anaerobic conditions may persist for as long as 4 years (Segerstråle, 1969). Total absence of oxygen, beginning in 1957, caused the deeper parts of the Gotland, Gdansk, and Bornholm Basins to become lifeless deserts in 1958-59. The total area affected was estimated at 33,000 km^2. The stagnation was broken in 1962 by a strong inflow of saline water from the Kattegat. It is significant that great amounts of nutrients accumulated during the stagnation period; these were brought to the surface in 1962, resulting in an enormous increase in plankton populations. A similar event had occurred in the early 1930's (Kalle, 1943; Meyer and Kalle, 1950). The most recent intrusion of North Sea water into the Baltic occurred in 1975 (Tiews, 1976) following several years of increasing oxygen depletion in bottom waters. This situation of periodic stagnation, broken by saline inflows, followed by uplift of nutrients, favors periodic increase in biological production, unlike other areas of continuous anaerobiasis such as the deeper (below 100 m) zones of the Black Sea, which constitute a nutrient sink and are unproductive.

Oxygen depletion of bottom waters, with accompanying formation of hydrogen sulfide, occurred in Tokyo Bay in 1972 (Tsuji et al., 1973; Seki et al., 1974), presumably related to an extensive red tide. Since red tides are becoming increasingly frequent in eutrophic bays in Japan as well as elsewhere in the world, anoxic conditions in bottom waters can be expected to increase in severity concomitantly. Mortalities of benthic organisms, associated with bottom water of low oxygen content, occurred in the Gulf of Trieste, in the North Adriatic in 1974 (Fedra et al., 1976). The authors reported scattered areas of decaying organisms in a region formerly characterized by stable benthic populations.

Oxygen depletion has occurred sporadically in Mobile Bay, Ala., one of the largest estuaries on the Gulf of Mexico. Stratification of the water column over highly organic bottom results in summer oxygen depletion, and occasionally, because of winds, the water mass impinges on beaches. Fish and invertebrates may be trapped in the anoxic water near beaches, often in a disoriented or moribund condition, where they are taken in great numbers by residents. The shoreline phenomenon is

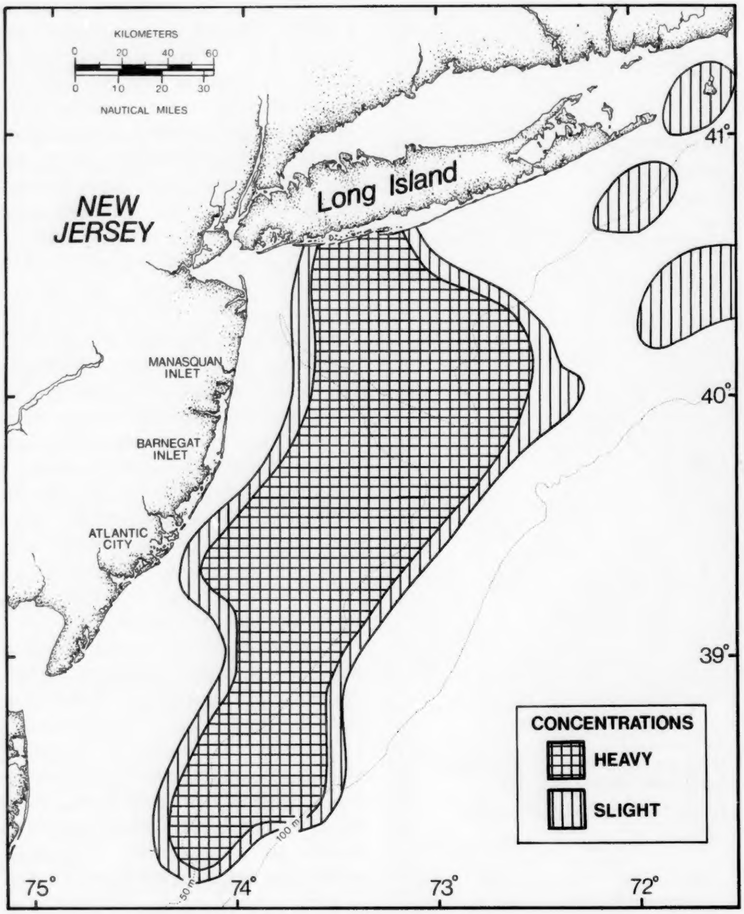

Figure 6.—Distribution and relative abundance of *Ceratium tripos* bloom during early spring 1976.

called a "jubilee." Thirty-five such occurrences were reported by Loesch (1960) between 1946 and 1956, but newspaper accounts go back to the 19th century (the earliest being in 1867). May (1973) has reviewed the history of such events and finds no increase in their frequency in recent years. He carried out detailed oxygen determinations during a "jubilee" in 1971 and found large areas of the bay with less than 1 ppm dissolved oxygen in bottom water. Mortalities of fish, crabs, and oysters were observed.

There have been previous reports of fish kills off New Jersey in 1968, 1971, and 1974 (Ogren, 1969; Ogren and Chess, 1969; Young, 1973, 1974[2]), and there may have been earlier problems that were not observed or reported. Those which were documented resemble the events of 1976 in that: 1) The more sedentary organisms found around rocks and wrecks and near open bottom were killed; 2) reports originated from the same general area off central New Jersey; 3) depressed oxygen levels were considered a major contributing factor, and 4) suspended flocculent material was present in the water column. The 1976 episode differed from previous years in that: 1) It began earlier before the end of June, compared with the August-October period of earlier problems; 2) the bottom water was cooler (ca. 10°C) than reported in earlier publications (14°-18°C), and 3) hydrogen sulfide, not previously reported, was detected in 1976 in lethal concentrations. It may have been present but not observed in earlier episodes.

The previous reports of mortalities also covered a much smaller area. The 1968 event, which appears to have been the most extensive of the earlier kills, included a zone from north of Long Branch to south of Barnegat Inlet, N.J. (a 70-km distance), from 1 to about 10 km offshore, with a total area of approximately 600-800 km² (Ogren and Chess, 1969). Mortalities were reported on and near wrecks and reefs from early September until late October 1968. Species affected were ocean pout (*Macrozoarces americanus*), cunner (*Tautogolabrus adspersus*), lobster (*Homarus americanus*), rock crabs (*Cancer irroratus*), mussels (*Mytilus edulis*), surf clams (*Spisula solidissima*), and starfish (*Asteria* sp.). More active species, such as tautog (*Tautoga onitis*), black seabass (*Centropristis striata*), squirrel hake (*Urophycis chuss*), conger eels (*Conger oceanicus*), and round scad (*Decapterus punctatus*), apparently were able to escape and were rarely reported among the mortalities. Fauna on wrecks off Barnegat and Atlantic City, N.J., was normal.

Reexamination of the same area in May and July 1969, disclosed that oxygen values near the bottom were in excess of 7.0 ml/l, and that wrecks had been repopulated by fish and crustaceans. No reports are available for 1970, but in early October 1971, lobsters and rock crabs were reported dead on several wrecks 12 km east of Manasquan Inlet in depths of about 30 m, and also at Shark River Inlet, north

[2]Young, J. S. 1974. Unpublished data. Middle Atlantic Coastal Fisheries Center, National Marine Fisheries Service, NOAA, Highlands, N.J. Pers. commun. to J. B. Pearce.

of Manasquan Inlet (Young, 1973). Bottom water temperatures were high (18°C) and suspended flocculent material was noted low in the water column.

Again no reports are available for 1972 and 1973, but in August 1974, mortalities of ocean pout were observed on several wrecks off Manasquan Inlet (Young, footnote 2). Bottom dissolved oxygen values were 1.0 ml/l, with heavy suspended flocculent material and bottom water temperatures of 14°-15°C. In early September 1974, the *Subsea Journal* of the Manta Ray Diving Club of New Jersey reported dead lobsters and rock crabs on a wreck south of Manasquan Inlet.

Thomas et al. (1976) reported that significant summer depletion of bottom D.O. in the restricted area of the sludge and dredge spoil dump sites, and also in an area close to the New Jersey shore off Asbury Park, 10 km north of Manasquan Inlet, occurred during the summer of 1974. Low D.O. values have been reported previously in the New York Bight dump-site areas (Pearce, Segar and Berberian, 1976). D.O. values in dump-site areas in summer of 1975 were higher than 1974, and above the level considered harmful to most marine life.

CONCLUSION

The appearance and persistence of a massive bloom of the dinoflagellate *Ceratium tripos* in the Middle Atlantic Bight in 1976 is considered to be a significant factor contributing to oxygen depletion. Beginning in February, an unusual bloom of the dinoflagellate was found to be in progress over most of the outer continental shelf area of the Middle Atlantic Bight. This bloom was also noticed at many stations during an ichthyoplankton survey during March; the dinoflagellates clogged coarse-mesh nets from Long Island to Virginia in abundances which had not been observed in the 10 years previous experience of the ichthyoplankton group sampling in this area (Smith, footnote 1) (Fig. 6).

With onset of stratification, the bloom became concentrated in a band at or below the thermocline, within 100 km of the New Jersey coast. The *Ceratium* population appeared to decline sharply by July, and its contribution to bottom oxygen depletion in June and July was strongly indicated by the accumulation on the bottom of 1 cm or more of a brown flocculent material, which consisted to a large extent of dead *Ceratium*. Additionally, the observation in late spring and early summer that much of the bloom was concentrated at or below the thermocline indicates another possible mechanism of oxygen depletion, since the organism may exist heterotrophically. *Ceratium* is not grazed upon by many planktonic herbivores, so the persistent bloom over a period of several months meant the accumulation of large amounts of oxygen-demanding organic material in the water column, and the gradual accretion of dead organic material on the bottom. All of this oxygen-consuming material, when combined with the unusual hydrographic events mentioned earlier, seems to provide a reasonable explanation for the observed extreme oxygen depletion in 1976 (Mahoney, 1977; Malone, 1977).

Annual phytoplankton blooms are now a reality in sections of the New York Bight, probably in part at least as a consequence of organic loading of coastal waters, particularly from the Hudson River. The mean residence time calculated for the New York Bight is 100-250 days, and estimated daily chemical inputs from the Hudson River estuary complex alone are 520 t of nitrogen and 138 t of phosphate. Sewage sludge dumping and other human sources of nutrients have been estimated to augment these figures by only minor amounts (<10 percent).

In total though, when natural productivity of coastal waters is locally enriched by nutrients of human origin, a condition of increasing eutrophication can develop—and oxygen depletion can be a consequence. It does seem, however, that the extent and duration of the 1976 *Ceratium* bloom in the Middle Atlantic Bight would indicate that it did not occur in response to local nutrient inputs, but was rather a shelf-wide long-term phenomenon.

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Townsend Cromwell Charts Guam, Marianas Marine Resources

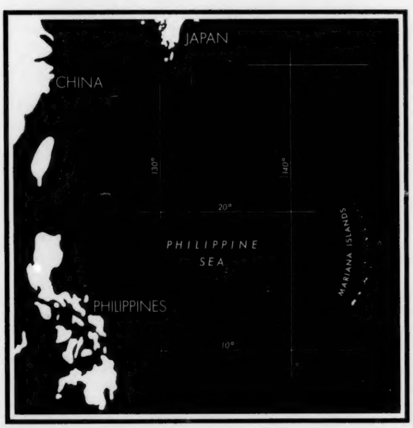
The NOAA ship *Townsend Cromwell* operated by the National Ocean Survey and attached to the National Marine Fisheries Service in Honolulu, returned to Honolulu on 21 July after completing a 10-week survey and assessment cruise to waters around Guam and the Northern Mariana Islands. The primary mission for the cruise was to investigate the marine resources around these islands and identifiy those that have the greatest potential for early development. According to Richard S. Shomura, Director, Honolulu Laboratory, National Marine Fisheries Service, NOAA, this cruise was a joint effort of NMFS, the Guam Division of Fish and Wildlife, the University of Guam Marine Laboratory, and the Northern Marianas Fishing Authority. This timed major survey of the waters around Guam and the Northern Marianas will provide information which the governments of Guam and the Northern Marianas can use in planning their fishery development programs, said Shomura.

Using a variety of fishing gear including traps, handline, bottom trawls, and trolling lines, scientists aboard the *Townsend Cromwell* found relatively few areas with high densities of commercially valuable species such as ulua or jacks, snappers, and pandalid shrimps. However, bigeye scad or akule was notably abundant along the seamounts such as Arakane Reef, Pathfinder Reef, and other unnamed seamounts. Night "jigging" for bigeye scad during the dark moon phases of the month was particularly effective at some of the night-light fishing stations over the seamounts, said Richard N. Uchida, Chief Scientist on the cruise. Handline fishing produced good catches of gindai and ulua at several of the offshore seamounts.

The survey also revealed that relatively high densities of pandalid shrimps occur in certain areas around Guam and the Northern Marianas. According to Uchida, these shrimps were caught in pots set in waters ranging from 365 to 820 m in depth. The catch rate was highest in waters off Guguan Island where it reached 175 shrimps per pot at depths of 640-730 m.

Trolling was also very productive over some of the offshore seamounts and catches included yellowfin tuna, skipjack tuna, and rainbow runner. Of 226 fish caught by trolling, 114 were tagged and released. When recaptured, these tagged fish will provide information on migration patterns and growth.

In general, it appeared that the offshore seamounts were more productive fishing grounds compared with locations close to the high islands, said Uchida. The handlining catch reached 1.9 fish per line-hour over the seamounts, whereas it was only 1.0 fish per line-hour at stations near the high islands. Of course, these catch rates are based only on the results of one cruise and may be due to seasonal variation in the distribution and abundance of the fish, cautioned Uchida. It was also noted that two species of spiny lobsters are known to occur in the Northern Marianas and both were taken in lobster traps during the cruise. However, these species are primarily reef-dwelling forms and very few were caught in the offshore zone where the *Townsend Cromwell* fished. Likewise, trawling for bottom fish using a Norwegian fish trawl was generally unproductive. The *Townsend Cromwell* also conducted coral-drag operations in depths ranging from 42 to 450 m of water, but no potentially valuable precious coral grounds were located.



COMPUTERS MAY AID FISHING INDUSTRY

Can computers reduce the risk of failure in the fishing business? Economists at five universities across the country, supported by a $138,100 grant from NOAA, think so and are setting out to prove it.

Ned A. Ostenso, Director, Office of Sea Grant, said aquaculture and fishing ventures traditionally have been subject to financial loss or failure because of unexpected rises in costs, and other problems. "This project aims to develop a computer-model budget and the necessary data base to help the fishing industry improve its chances of success," he said.

The project will bring together experienced economists from Texas A&M University, the University of Massachusetts, Oregon State University, Louisiana State University, and the University of Rhode Island to develop necessary analytical tools and techniques that others can use.

A general computer program will be developed that can be applied to most aquaculture systems and many different fishing vessels to predict the probable outcome of a particular venture. Economic analyses then will be prepared for high priority species of fish within each region of the country represented by the participating scientists.

Data for the aquaculture phase of the project will include such species as salmon, marine shrimp, oysters, freshwater prawns, and lobster. Information on vessels which fish specifically for lobster, groundfish, shrimp, snapper-grouper, tuna, crabs, salmon, and halibut also will be included. Problems will range from determining which type of equipment would be most cost effective for a particular aquaculture venture to assessing the effect of changes in tax laws for vessel owners with respect to crews and imported products used in fishing. The five cooperating universities will provide $82,400 in matching funds.

LSU DESIGNATED A SEA GRANT COLLEGE

Louisiana State University (LSU) has been designated a Sea Grant College, Secretary of Commerce Juanita M. Kreps has announced, in recognition of the excellence of the institution's marine resources program. LSU is the 13th institution in the United States to attain Sea Grant College status.

"The Sea Grant program at Louisiana State University, now in its eleventh year, has served as the stimulus for development of a broad program in marine affairs," Secretary Kreps said. "The focus of education, research, and marine advisory service components of the program is on the wise use, management, and conservation of renewable natural resources offshore and in the coastal zone."

Ned A. Ostenso, Director of the National Sea Grant Program, an element of the National Oceanic and Atmospheric Administration (NOAA), said the designation underlines the institution's strong development in marine resource activities and the cooperation between the University, the State, and the Federal Government. The National Sea Grant Program has awarded grants to universities, laboratories, and other institutions since 1968, supporting research, education, and advisory services that foster development of the nation's marine resources. Operating under a matching fund arrangement, the Sea Grant Program includes more than 690 projects at approximately 130 colleges, universities, and institutions.

The Sea Grant Program at LSU is centered on the University's Baton Rouge campus, where, according to LSU System President Martin D. Woodin, it has had a deep influence resulting in a strong commitment to marine affairs. "An example of this has been the establishment of the Center for Wetland Resources, which includes the Coastal Studies Institute, the Laboratory for Wetland Soils and Sediments, the Coastal Ecology Laboratory, and the Department of Marine Sciences," he said.

Sea Grant research activities at LSU have focused to a large extent on local and regional needs. Detailed ecological studies were made in the Barataria Basin, for example, which led to major findings regarding productivity of the coastal marshes and related effects of human activity. In other areas, LSU Sea Grant researchers have achieved success in studies dealing with international and coastal law, in projects on rearing of shrimp and crawfish, in a program of immunization for farm-raised alligators, in expansion of public understanding of the oceans at all age levels, and in a marine advisory service program designed to uncover problems faced by fishermen, aquaculturists, food processors, and other marine users for presentation to researchers and for relaying research results to those users.

SATELLITE CHECKS OCEAN POLLUTION

Two highly complex instruments carried into space with the launch of the Nimbus-G satellite in late 1978 hold promise of providing scientists with the answers to two basic questions of importance to mankind: 1) How polluted are the world's oceans becoming, and 2) is the earth warming up or cooling down? The instruments are vital to studies being conducted by scientists with the National Oceanic and Atmospheric Administration (NOAA), as well as to other researchers concerned with the oceans and the atmosphere.

Nimbus-G, a research and development satellite managed for the National Aeronautics and Space Administration by its Goddard Space Flight Center, Greenbelt, Md., was scheduled for launch from NASA's Western Test Range in Lompoc, Calif. One instrument, the Coastal Zone Color Scanner, is expected to aid oceanographers in determining the content of water, important in monitoring water pollution, according to Warren A. Hovis, Jr., Director of the Satellite Experiment Laboratory of NOAA's National Environmental Satellite Service. NOAA is a Commerce Department agency.

The scanner, sensing the colors in water beneath the polar-orbiting satellite, will permit content analyses to be made of large areas of coastal or ocean waters, "letting oceanographers view the ocean as never seen from ships," Hovis said. The instrument will be used to determine how well water pollution—such as oil spills, sewage and industrial waste dumpings, and river sediment—can be detected and tracked.

The other instrument, the Earth

Radiation Budget experiment, makes a variety of measurements of the radiation coming from the sun and the earth. Of particular interest to scientists is the observation of variations in the radiative heat exchange between the sun and earth with time, with location on the earth, and over the entire globe.

NOAA's Herbert Jacobowitz, of the Satellite Service's Meteorological Satellite Laboratory, said such observations can help in monitoring, and perhaps eventually anticipating, the fluctuations in climate from months to a few years. This, he explained, is because this radiative heat exchange creates the basic energy source for the atmospheric and oceanic circulations that determine climate. For example, variations in radiative heating between the tropics and higher latitudes, or between the oceans and continents, may yield important clues as to the types of winters or summers that may be expected to occur in the United States or other parts of the world.

New Technique Tracks Sewage Dumped At Sea

National Oceanic and Atmospheric Administration (NOAA) scientists have identified a biochemical technique that can be used to trace sewage in coastal areas, a matter of vital interest to environmental managers in heavily populated parts of the coast. The newly identified technique uses coprostanol, a steroid thought to be produced exclusively by bacteria in the intestines of mammals, to measure sewage in offshore sediments.

According to Patrick G. Hatcher, Philip A. McGillivary, and NOAA Corps Lieutenant Commander Larry E. Leister, all of NOAA's Atlantic Oceanographic and Meteorological Laboratories in Maimi, the coprostanol method promises to become the standard for sewage-pollution detection. Hatcher and his colleagues developed the technique as part of a major ecosystem study NOAA has conducted in the New York Bight, the 15,000-square-mile (39,000-km^2) continental shelf area off the New York-New Jersey coast.

Because sewage sludge, the end product of waste-water treatment, is dumped in the Bight, scientists and citizens are concerned about sewage contamination there. But sewage is difficult to trace in the chemically complex marine environment, Hatcher said. The Commerce Department researchers turned to steroids, biochemical compounds that resist deterioration in the environment. The steroid coprostanol was found to be present in contaminated marine sediments, but not in uncontaminated sediments, and appeared to be stable enough to be used as a tracer of sewage. Subsequent work led to a "percent-coprostanol" term that permits the scientists to estimate how much of a sample's organic matter is sewage-derived.

With the technique, a map of the New York Bight has been developed showing sewage pollution centered in a basin near the sewage-sludge dump site, and diminishing rapidly with distance away from the dump site. The highest value found was 15 percent coprostanol in the highly contaminated black muds near the dump site. Pure sewage contains more than 30 percent.

Substances From Sea Creatures May Have Medical Applications

Twelve chemical compounds recently discovered in such sea creatures as sponges, sea cucumbers, and sea hares potentially are valuable in treating cancer, central nervous system disorders, and cardiovascular problems, researchers supported by the National Oceanic and Atmospheric Administration (NOAA) believe. The scientists, from the University of Oklahoma, have isolated and identified the compounds during the past 15 months, and now are beginning further study on their application to disease. The research is supported by a $116,500 Sea Grant from NOAA, a Commerce Department agency, and $58,258 in supplemental funds from the University.

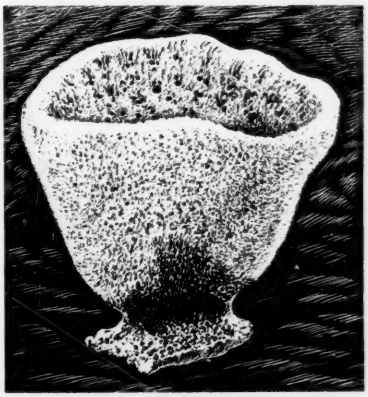
One of the most promising substances for the treatment of nervous disorders is found in the sea hare—a member of the shellfish family—and is known as dactylene. The substance may inhibit the breakdown in the body of barbiturates, which are used to induce sleep and can be addictive. Inhibition of their breakdown would prolong their effects and permit use of smaller and safer doses. Dactylene has been tested on rats and mice, and increases the length of time the laboratory animals sleep after being given a barbiturate.

Other newly identified compounds suppress cellular growth in tissue and are candidates for possible anticancer treatment, according to the research team. The scientists are now conducting experiments on laboratory animals to validate the effects of the substances.

Chemicals taken from a number of Caribbean invertebrates and algae have, in the laboratory, inhibited the growth of experimental tumors in mice, and also mitigated cardiovascular and central nervous system disorders induced in small mammals. Isolation and identification of these substances will continue under the NOAA grant.

The newly discovered compounds may serve as models for the synthesis of new drugs. Additionally, the chemical information gained from the research will increase knowledge of the chemistry of marine animals and plants, and define the types of compounds released into seawater from natural sources.

Elephant's ear sponge.



Peru Reduction Fishery Drops 50 Percent in 1977

Peru's 1977 catch of fish for reduction decreased substantially to 2,020,000 metric tons (t), or 50 percent less than in 1976. The country's total fisheries catch in 1976 was 4.343 million metric tons, according to FAO statistics. While the country was able to get through the year without major changes in its imports, prospects for an even lower 1978 fisheries catch were expected to result in considerably larger soybean oil imports.

Table 1.—Peru's fish oil supplies and distribution in calendar years 1976-78. Source: Ministry of Fisheries, trade and Attache's estimates.

Item	1976 (Final)	1977 (Preliminary)	1978 (Forecast)
Supplies (×1,000 t)			
Opening stocks (1 Jan.)	7	8	16
Production	104	101	[1]60
Total	111	109	76
Distribution			
Exports	—[2]	0	0
Apparent consumption			
Edible	98	83	56
Industrial[3]	5	10	10
Subtotal	103	93	66
Ending stocks (31 Dec.)	8	16	10
Total distribution	111	109	76

[1]Based on a 1.5 million t fish catch (anchovy, sardines, jurel, and needlefish).
[2]20 t hydrogenated fish oil exported to Bolivia.
[3]Soap industry.

Table 2.—Peru's consumption of fats and oils in calendar years 1976-78. Sources: Trade and Attaché's estimates.

Item	1976 (Final)	1977 (Preliminary)	1978 (Forecast)
Fish oil (×1,000 t[1])			
Liquid oil[2]	45.1	43.7	16.0
Solid fats (margarine and shortening)	53.3	38.8	40.0
Soap industry	5.0	10.0	10.0
Total	103.4	92.5	66.0
Per capita consumption, edible, (kg/year)			
Vegetable oil	6.1	5.7	7.3
Fish oil	6.2	5.0	3.3
Lard	0.5	0.5	0.5
Total	12.8	11.2	11.1

[1]Unless otherwise indicated.
[2]For making blended cooking oil.

Peru's production of fats and oils was also forecast to decrease from 135,300 t in 1977 to only 97,200 t in 1978, down 28 percent, due to the unfavorable anchovy fishery. The output of fish oil was forecast to decline 40 percent in 1978 (Table 1).

In a surprising development, the Ministry of Fisheries authorized the catch of sardines, jurel, and needlefish as of 17 April 1978. Publicly announced forecasts estimated the 1978 catch of reduction fish at 1.5 to 1.8 million tons, fish meal production at 300,000 to 350,000 tons, and fish oil production at 60,000 to 70,000 tons. All figures are revised slightly downward from earlier estimates.

In 1976 and 1977, fish oil represented roughly 46 percent of Peru's total consumption of fats and oils. Based on the 1978 unfavorable fishing forecasts, fish oil should constitute only about 32 percent of Peru's total fats and oils requirement this year. According to various sources, no more than 120,000 t of fish oil (4 million t anchovy catch) is expected in the coming years.

Tables 2 and 3 show the supply and distribution of fish oil and fish meal, respectively, for calendar years 1976-78. As can be seen by Table 3, a reduction in fish meal consumption of 35,000 t from 1977 to 1978 was expected. The decline in 1978 fish oil and fish meal production is due to the reduced fisheries catch. Domestic production has a direct bearing on the availability of fish meal for export. (Source: IFR-78/102.)

Table 3.—Peru's fish meal supplies and distribution in calendar years 1976-78. Sources: Ministry of Fisheries, Trade and Attaché's estimates.

Item	1976 (Final)	1977 (Preliminary)	1978 (Forecast)
Supplies (×1,000 t)			
Opening stocks (1 Jan.)	40	172	112
Production	886	493	300
Total	926	665	412
Distribution			
Exports	624	436	300
Apparent consumption	130	117	82
Ending stocks (31 Dec.)	172	112	30
Total	926	665	412

[1]Based on a 1.5 million t fish catch (anchovy, sardines, jurel, and needlefish).

Japan, Russia Negotiate Joint Fishing Ventures

Soviet Fisheries Minister Aleksandr A. Ishkov informed Japan Fisheries Association President Tomoyoshi Kamenaga earlier this year that his Ministry had received five or six applications from Japanese trading firms to form joint ventures with the Soviet Union. The Japanese companies were seeking access to the Soviet 200-mile zone in areas now closed to Japanese fishing vessels under the existing Provisional Japan-Soviet Fisheries Agreement.

The two men met the day after the signing of the Five-Year Japan-Soviet Fisheries Cooperation Agreement in Moscow. Ishkov stated that the U.S.S.R. was willing to enter into several joint ventures as soon as the Japanese Government determined which requests would be approved. The deadline set for the Japanese response was 10 May. Conditions set forth then by Ishkov were: 1) Fishing vessels of the two countries would operate separately in the same area; 2) 25 percent of the Japanese catch would be transferred to the U.S.S.R. as a fishing fee; and 3) Japan would buy back this 25 percent as well as purchase the Soviet catch.

The Japanese Fisheries Agency (JFA) had approved, as of 6 June, five of the six proposed joint operations. The JFA indicated that it would only

Unless otherwise noted, material in this section is from the Foreign Fishery Information Releases (FFIR) compiled by Sunee C. Sonu, Foreign Reporting Branch, Fishery Development Division, Southwest Region, National Marine Fisheries Service, NOAA, Terminal Island, CA 90731, or the International Fishery Releases (IFR) or Language Services Daily (LSD) reports produced by the Office of International Fisheries, National Marine Fisheries Service, NOAA, Washington, DC 20235.

permit those Japanese companies to participate which previously fished within the Soviet 200-mile zone. All Japanese trading companies would be excluded. This decision by the JFA was delayed past the 10 May deadline proposed by Ishkov owing to the following two concerns.

1) The joint operation plans should be conducted separate from the Japan-Soviet Provisional Fisheries Agreement and should not adversely affect the 850,000 metric ton (t) 1978 Soviet quota for Japanese vessels fishing within the Soviet 200-mile zone.

2) Japanese fishing companies and organizations should take the initiative in concluding contracts with the U.S.S.R., although the trading companies originated the plans and filed the applications.

According to later information received from the U.S. Regional Fisheries Attache in Tokyo, the JFA and the Soviets agreed to proceed with four of the six proposed joint ventures (Table 1). Alaska pollock was excluded because it is a migratory fish and not limited to the continental shelf. Blue king crab was also deleted, apparently at the insistence of the Soviets (Table 2).

The Japanese have agreed to provide the Soviets with information on Japanese fishing methods, especially basket-net fishing, and the Soviets will place fishermen as observers on Japanese vessels involved in the joint operations. The question of fees is still being negotiated. The Japanese Government will decide about participation in joint ventures next year after viewing this year's results. Japanese vessels will be issued temporary licenses and will not be eligible for government compensation should the program be discontinued next year.

According to the NMFS Office of International Fisheries the status of the proposed Soviet-Japanese joint ventures at midsummer was unclear. The Japanese Government announced on 22 June that they had recently been informed by the Soviet Union that the Soviets would not be able to carry out the joint fishing ventures as had been agreed. The reason given, according to a Japanese Government source, was Moscow's displeasure with the resumption of treaty talks between Japan and the People's Republic of China. This announcement came just as the joint ventures were about to begin operations. It was also announced at that time, that the Soviets would not allow the resumption of kelp (konbu) gathering by small-scale Japanese fishermen off Soviet-held Kaigara Island.

An official Moscow source denied in 23 June that the Soviets had cancelled the joint ventures. At the same time, this official source would not say definitely whether negotiations on the joint ventures and kelp gathering would continue as before. Even so, on 4 July, the Soviet Union notified the Japan Fisheries Association that there would be a further delay in joint venture talks owing to disagreements among Soviet authorities. (Source: IFR-78/125.)

Table 1.—U.S.S.R.-Japan planned joint fishing operations, 1978.

Japanese company or organization					Vessels					
					Japanese			Soviet		
Fishery	Trading	Species	Quota (t)	Area	No.	Type	Size[1]	No.	Type	Size[1]
Hoko Suisan & Nichiro Gyogyo	Marubeni	Tanner crab	3,000	Olyutorskii Bay	1 2 3	Reefer Sub-reefers Pot-vessels	1,000 400 96	2	NA	150
Hamaya Suisan[2]	Tokyo Maruichi Shoji	Pink shrimp	700	Southwest Kamchatka	1	Shrimp trawler	NA	1	NA	NA
Japan Sea Shrimp Pot Fishing Council	Yokohama Tsusho	Pink shrimp	700	Marmiya Straits	7	Pot-vessels	96	2	NA	NA
Okhotsk Sea Hair Crab Fishing Council	Tokyo Maruichi Shoji	Hair crab	500	Southwest Sakhalin	1 1	NA NA	299 NA	1	NA	NA

[1]Gross registered ton per vessel.
[2]The company is located in Wakkanai, Hokkaido.
Source: Regional Fisheries Attache, U.S. Embassy, Tokyo.

Table 2.—U.S.S.R.-Japan joint fishing operations not approved, 1978.

Japanese company or organization					Vessels					
					Japanese			Soviet		
Fishery	Trading	Species	Quota (t)	Area	No.	Type	Size[1]	No.	Type	Size[1]
Medium Trawler Owners	Tairiku Boeki	Pollock	20,000	Southern Kamchatka	12	Medium trawlers	NA		— None —	
Taiyo Gyogyo	Morikawa Shoji	Blue king crab	1,000	Olyutorskii, Naarin Bays		NA	400		— None —	

[1]Gross registered ton per vessel.
Source: Regional Fisheries Attache, U.S. Embassy, Tokyo.

Kamaboko Reportedly Made From Krill

Japan's National Federation of Kneaded Fisheries Products Cooperatives announced last summer the successful development of "kamaboko", a heat-pasteurized fishcake, using Antarctic krill. The test product reportedly excelled the quality of the Alaska pollock-based kamaboko in nutritional value and taste, and possessed desirable flavor, color, and texture.

Commercial production was expected to encounter such problems as difficulty of using ordinary mechanical peelers, low yield of krill meat (averaging about 8 percent of body weight), and a strong tendency for the krill meat to oxidize, which would necessitate mothership production of krill-based kamaboko.

(Source: FFIR 78-10.)

NMFS Scientific Reports Published

NOAA Technical Report NMFS SSRF-720. Squire, James L., Jr. **"Sea surface temperature distributions obtained off San Diego, California, using an airborne infrared radiometer."** March 1978. 30 p. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

ABSTRACT

Sea surface temperature surveys were conducted weekly off San Diego, Calif., using an airborne infrared radiometer from April through October 1972-74. A total of 90 surveys were made over the 320-mile flight track. The analog chart record of temperature was keyed to a "ground truth" temperature measurement and read to determine 1 min average temperatures which were plotted on the flight track and 1°F (0.56°C) isotherms were contoured from the data. The trend of sea surface temperatures during the 3-year period showed warmer temperatures in 1972, which was an "el Niño" year, cooler in 1973, warmer than 1973 in 1974, but not as warm as 1972. In early July 1974, an anomalous warming period occurred and highest average temperatures of 73°F (22.7°C) were recorded in 19 July 1974. Lowest average temperature of 54°F (12.2°C) was recorded on 2 April 1973.

The 1972-74 survey temperatures taken over the "ground truth" calibration site were compared with a time series of temperature observations taken during the same months from 1963 to 1968. The average temperature during 1963-68 was 63.4°F (17.4°C) and for 1972-74, 64.1°F (17.8°C), a difference of less than 1°F (0.56°C). Average monthly temperature differences, 1963-68 compared with 1972-74, shows April the same, warmer 2°F (1.12°C) for May, 3°F (1.68°C) for June, 1°F (0.56°C) for July, same for August, 1°F (0.56°C) less for September, and 2°F (1.12°C) less for October.

NOAA Technical Report NMFS SSRF-725. Davis, Clarence W. **"Seasonal bottom-water temperature trends in the Gulf of Maine and on Georges Bank, 1963-75."** May 1978. 17 p.

ABSTRACT

Spring (1968-75) and autumn (1963-75) bottom-water temperature temperatures in the Gulf of Maine and on Georges Bank were analyzed to investigate a suspected warming trend in the region. During the spring the mean temperature in the Gulf of Maine increased rather steadily from a low of 5.4°C in 1968 to a high of 6.4°C in 1974. Various subareas of the Gulf had more frequent and greater oscillations but exhibited the same overall warming trend. Mean spring temperatures on Georges Bank fluctuated from 3.8°C in 1968 to 6.3°C in 1974 and declined by nearly 2°C in 1975 with similar characteristics in eastern, central, and western subareas of the Bank.

During the autumn in the Gulf, bottom-water temperatures reached a minimum of 5.4°C in 1966, increased to a maximum of 8.4°C in 1973 and 1974, but declined to 8.0°C in 1975. Subareas of the Gulf generally showed the same temperature trends from 1963 to 1968; especially notable are the cooling trend west of long. 69°W which commenced in 1971, and a decrease in all five subareas in 1975. Georges Bank temperatures in autumn declined from a maximum of 13.1°C in 1965 to a minimum of 10.4°C in 1969, reached another peak of 12.6°C in both 1973 and 1974, but declined to 11.6°C in 1975. Subareas of Georges Bank generally followed the same pattern with the eastern third of the Bank usually 2°C or colder than either of the other subareas in the autumn.

The average bottom-water temperatures during spring were 5.0°C on Georges Bank and 6.1°C in the Gulf of Maine; temperatures in the autumn were 11.7°C and 7.2°C, respectively, for these areas.

NOAA Technical Report NMFS Circular 411. Dooley, James K. **"Systematics and biology of the tilefishes (Perciformes: Branchiostegidae and Malacanthidae), with descriptions of two new species."** April 1978. 78 p.

ABSTRACT

Tilefishes have been examined on a world basis with the following conclusions: 1) Tilefishes belong to two distinct phyletic lines here designated as the family Branchiostegidae and the resurrected family Malacanthidae. 2) The Branchiostegidae include 3 genera and 21 species. 3) The Malacanthidae include 2 genera, 2 subgenera, and 8 species. 4) A new species, *Caulolatilus hubbsi*, is described from off southern California, the Gulf of California, the Galapagos Islands, and from Callao, Peru; it is generally found sympatrically with the other two eastern Pacific species of *Caulolatilus*. 5) A second new species, *Branchiostegus albus*, is described from off central Honshu, Japan; Pusan, Korea; along the coast of the East China Sea including Shanghai and Taiwan; and the coasts of the South China Sea including Hong Kong and Macao. *Branchiostegus albus* was formerly confused with *B. argentatus* Cuvier 1830. 6) Branchiostegids are generally relatively deep dwelling (20-600 m;

usually deeper than 50 m) fishes found along the edges of continental margins, near the upper slope of islands, or at the heads of deep-sea canyons. These fishes are deep bodied and have prominent skull crests. 7) Malacanthids are relatively shallow-water (10-150 m, usually shallower than 50 m), burrow-dwelling or mound-building fishes with elongate bodies and rounded or flat skulls with no prominent crests. 8) Tilefishes appear to have basal percoid affinities, having a number of larval and osteological characters found among beryciform fishes (considered antecedent to perciforms) and characters considered primitive among perciform fishes.

NOAA Technical Report NMFS SSRF-721. Hall, R. A., E. G. Zook, and G. M. Meaburn. **"National Marine Fisheries Service survey of trace elements in the fishery resource."** March 1978. 313 p.

ABSTRACT

Trace element levels have been determined in tissues of 204 species of finfish, Mollusca, and Crustacea taken from 198 sites around the coastal United States, including Alaska and Hawaii. The survey was undertaken as part of the Microconstituents Program of the National Marine Fisheries Service, and covers the occurrence of 15 elements: antimony, arsenic, cadmium, chromium, copper, lead, manganese, mercury, molybdenum, nickel, selenium, silver, tin, vanadium, and zinc. Total concentraions of each element were determined without regard to chemical form. The species analyzed represent approximately 93 percent of the volume of the U.S. commercial and sportfish catch. The analytical data are summarized in several ways in order to emphasize different aspects of the trace element distributions. Mean levels of each element are presented in relation to the number of species examined, the U.S. (commercial and sportfish) catch, and the U.S. catch intended for consumption. More detailed analytical data on all 15 elements are given for individual species with reference to tissue analyzed, length and weight of fish, and location of catch. For the most part, experimental results are presented without interpretive comment. Mean levels of mercury, the only element for which a regulatory action level is in force, were found to exceed 0.5 ppm Hg in species representing less than 2 percent of the U.S. catch intended for consumption.

Marine Recreational Fishing Symposium Proceedings Printed

Marine Recreational Fisheries 2 contains the proceedings of the Second Annual Marine Recreational Fisheries Symposium and was published by the Sport Fishing Institute in Washington, D.C. Objectives of the symposia series are to identify major recreational marine fisheries problems—biological, economic, and social—and to promote effective management practices, based on scientific principles, for the conservation of living marine resources.

The book's 20 chapters (symposium presentations plus discussions) were delivered by leading national and international authorities, many with the National Marine Fisheries Service. A talk on NMFS mission and goals and the 200-mile zone law was given by then-NMFS Director Robert Schoning. Richard Hennemuth contributed a talk on "Some Biological Aspects of Optimum Yield"; Grant Beardsley and Wesley Parks presented "Management of Western North Atlantic Bluefin Tuna Fisheries"; and Brian Rothschild, J. M. Gates, and A. M. Carlson coauthored "Management of Marine Recreational Fisheries." "Protection of Coastal Wetlands" was explained by Richard Gardner, acting director of NOAA's Office of Coastal Zone Management.

Other chapters discuss marine angling perspectives in both Canada and Mexico, the U.S. 200-mile zone law, criteria for collecting marine recreational fisheries data, attaining "clean water", effects of water development on striped bass, the tarpon's unusual biology and man's impact on its future, economic losses to marine recreational fisheries from habitat destruction, a model for determining optimum yield, human perspectives in optimum sustainable yield fisheries management, and "menhaden, sport fish and fishermen."

Symposium chairman was Richard H. Stroud of the Sport Fishing Institute; proceedings editor was Henry Clepper. The 220-page hardbound volume is available at $15 per copy from the International Game Fish Association, 3000 E. Las Olas Blvd., Fort Lauderdale, FL 33316. It will be a valuable addition to the marine recreational angling literature.

NEKTON VOLUME IS TRANSLATED

Nekton, by Yu. G. Aleyev, has been translated from the Russian by B. M. Meerovich and published by Dr. W. Junk b.v. – Publishers, P.O. Box 13713, 2501 ES The Hague, The Netherlands. The book is divided into three parts: 1) Systematics and geographical distribution of nekton; 2) fundamental nektonic adaptations; and 3) origins and ecological divergence of nekton. It provides a good review of Russian studies on the topic.

In the introduction, the author defines his terms, presents the history and task of nektonology, and describes nektonological investigation methods. Other chapters discuss maintaining the body suspended in the water, locomotion, reducing resistance to movement, controlling movement, camouflage and defense, other adaptations, classes of nekton and their origins, and nekton and the body of water. The 435-page book has 247 figures, contains an extensive literature cited section, indexes of author's names and animal latin names, plus a subject index. The listed price is 120.00 Dutch guilders.

Authors, Titles, and Subjects in *Marine Fisheries Review* Volume 40, Numbers 1-12, 1978

Indexed here by author, title, and subject are the papers which appeared in *Marine Fisheries Review* in 1978. A list of these papers, in numerical order, appears at the end of the Index. Entries are indexed by number and page (i.e., 7:12 indicates the July number, page 12).

Anonymous notes, news articles, and regular departments are not indexed.

T

Papers in *Marine Fisheries Review*

Volume 40, Numbers 1-12, 1978

JANUARY

FEBRUARY

1285. "The Pacific Northwest Commercial Fishery for American Shad," Norman B. Parks, 2:29-31.

MARCH

1286. "Immunity and Practical Vaccine Development," Albert L. Brown, 3:2-5.
1287. "Cellular Immunity in Fish as Measured by Lymphocyte Stimulation," M. Michael Sigel, John C. Lee, E. Churchill McKinney, and Diana M. Lopez, 3:6-11.
1288. "Immunization of Fish With Bacterins of *Aeromonas salmonicida*," L. R. Udey and J. L. Fryer, 3:12-17.
1289. "Immunization of Channel Catfish, *Ictalurus punctatus*, Against Two Bacterial Diseases," John H. Schachte, Jr., 3:18-19.
1290. "Immunization of Salmonids for Control of Vibriosis," J. L. Fryer, J. S. Rohovec, and R. L. Garrison, 3:20-23.
1291. "Vibriosis and Current Salmon Vaccination Procedures in Puget Sound, Washington," Lee W. Harrell, 3:24-25.
1292. "Epizootiology of Channel Catfish Virus Disease," John A. Plumb, 3:26-29.
1293. "Serological Screening of Channel Catfish Virus," Stewart McConnell and Jack D. Austen, 3:30-32.
1294. "A Herpesvirus Disease of Green Sea Turtles in Aquaculture," Harold Haines, 3:33-37.
1295. "Incidence of Disease in Warmwater Fish Farms in the South-Central United States," F. P. Meyer, 3:38-41.
1296. "Enteric Red Mouth Disease (Hagerman Strain)," R. A. Busch, 3:42-51.
1297. "Vibriosis and Furunculosis in Marine Cultured Salmon in Puget Sound, Washington," Anthony J. Novotny, 3:52-55.
1298. "Parasitic Diseases of Freshwater Fishes," W. A. Rogers, 3:56-57.
1299. "Ornamental Fish: Diseases and Problems," John B. Gratzek, Emmett B. Shotts, and Jack L. Blue, 3:58-60.
1300. "Shellfish Diseases," Louis Leibovitz, 3:61-64.
1301. "Control of Fish Diseases," S. F. Snieszko, 3:65-68.
1302. "Fish Disease Inspection and Certification," Diane Elliott, 3:69-71.

APRIL

1303. "Eels and Their Utilization," J. Perry Lane, 4:1-20.
1304. "Status of the Herring Stocks Fished by the Federal Republic of Germany Fleet," Holger Dornheim, 4:21-24.
1305. "Economic Aspects of the Development of the Herring Roe Gillnet Fishery, Southeastern Alaska, 1976," Howard O. Ness, 4:25-30.

MAY-JUNE

1306. "Trap Design and Ghost Fishing: An Overview," Ronald Joel Smolowitz, 5-6: 2-8.
1307. "Ghost Fishing of Vented and Unvented Lobster, *Homarus americanus*, Traps," K. J. Pecci, R. A. Cooper, C. D. Newell, R. A. Clifford, and R. J. Smolowitz, 5-6:9-43.
1308. "A Preliminary Study of Timed Release Mechanisms for Lobster Traps," Alan J. Blott, 5-6:44-49.
1309. "The Effects of Different Escape Vents on the Selectivity of Lobster Traps," Vernon E. Nulk, 5-6:50-58.
1310. "Trap Design and Ghost Fishing: Discussion," Ronald Joel Smolowitz, 5-6:59-67.
1311. "Annotated Bibliography on Lobster Trapping and Related Subjects," Ronald Joel Smolowitz, 5-6:68-77.

JULY

1312. "Charles Woods, Pioneer Scientist on Chemical Composition of Fish," Maurice E. Stansby, 7:1-4.
1313. "The San Diego Tuna Industry and Its Employment Impact on the Local Economy," Steven Rockland, 7:5-11.
1314. "*Portunus spinimanus* Latreille, a Portunid Crab With Resource Potential in the U.S. Virgin Islands," David A. Olsen, Arthur E. Dammann, and Joseph A. LaPlace, 7:12-14.
1315. "Mesh Selectivity of West Indian Fish Traps," David A. Olsen, Arthur E. Dammann, and Joseph A. LaPlace, 7:15-16.
1316. "The Pacific Northwest Commercial Fishery for Sturgeon," Norman B. Parks, 7:17-20.
1317. "The Atlantic Halibut and Its Utilization," J. T. R. Nickerson, 7:21-25.

AUGUST

1318. "An Analysis of the Charter Boat Fishing Industry on the Texas Gulf Coast," Robert B. Ditton, Richard N. Jarman, and Steve A. Woods, 8:1-7.
1319. "Characteristics, Participation, and Motivations of Texas Charter Boat Fishermen," Robert B. Ditton, Thomas J. Mertens, and Martin P. Schwartz, 8:8-13.
1320. "Preparation of a Menhaden Hydrolysate for Possible Use in a Milk Replacer," Malcolm B. Hale and Paul E. Bauersfeld, Jr., 8:14-17.
1321. "Seasonal Effect on Yield, Proximate Composition, and Quality of Blue Mussel, *Mytilus edulis*, Meats Obtained From Cultivated and Natural Stock," Bohdan M. Slabyj, Donn L. Creamer, and Ruth H. True, 8:18-23.
1322. "Catch-Effort and Price-Cost Trends in the Gulf of Mexico Shrimp Fishery: Implications on Mexico's Extended Jurisdiction," Vito Blomo, Wade L. Griffin, and John P. Nichols, 8:24-28.
1323. "Estimating the Structure of Capacity Utilization in the Fishing Industry," Kenneth Ballard and Vito Blomo, 8:29-34.

SEPTEMBER

1324. "Composition of the Edible Portion of Raw (Fresh or Frozen) Crustaceans, Finfish, and Mollusks. III. Microelements," Virginia D. Sidwell, Audrey L. Loomis, Karen J. Loomis, Pauline R. Foncannon, and David H. Buzzell, 9:1-20.
1325. "A Trawl Design: Employing Electricity to Selectively Capture Shrimp," Wilber R. Seidel and John W. Watson, Jr., 9:21-23.
1326. "Use of Carbon Dioxide Dissolved in Refrigerated Brine for the Preservation of Pink Shrimp (*Pandalus* spp.)," Harold J. Barnett, Richard W. Nelson, Patrick J. Hunter, and Herman Groninger, 9:24-28.
1327. "Status and Problems of the American Shrimp Industry," Roger W. Hutchinson, 9:29-31.

OCTOBER

1328. "Bacterial Diseases of Fishes and Their Control," S. F. Snieszko, 10:2-3.
1329. "Diseases and Defense Mechanisms of the Lobster, *Homarus americanus*," James E. Stewart, 10:4.
1330. "A New Bacterium (Presumptive *Vibrio* Species) Causing Ulcers in Flatfish," R. A. Robohm and C. Brown, 10:5-7.
1331. "Bacteriologic Studies of Long Island Shellfish Hatcheries," Louis Leibovitz, 10:8.
1332. "Vibriosis in Maine and New Hampshire Salmonids," Evelyn S. Sawyer, 10:9.
1333. "Anaerobic Bacteria as Possible Disease Agents in Fish," Lanny R. Udey, 10:10-11.
1334. "Recent Development in Channel Catfish Virus Research," J. A. Plumb and P. R. Bowser, 10:12.
1335. "Viral Diseases of the Blue Crab, *Callinectes sapidus*," Phyllis T. Johnson, 10:13-15.
1336. "Piscine Erythrocytic Necrosis (PEN): A Viral Infection of the Atlantic Cod and Other Marine Fishes," Paul Reno, Marie Philippon-Fried, Bruce L. Nicholson, and Stuart Sherburne, 10:16-17.
1337. "Viruses and Viruslike Lesions in Marine Mollusks," C. Austin Farley, 10:18-20.
1338. "Viruses and Virus Diseases of Salmonid Fishes," Philip E. McAllister, 10:21-23.
1339. "Phosphonoacetic Acid Inhibition of Channel Catfish Virus Replication," Roger W. Koment, 10:24-25.
1340. "Comments on Trends in Research on Parasitic Diseases of Shellfish and Fish," Victor Sprague, 10:26-29.
1341. "Susceptibility Studies of Various Salmonids to Whirling Disease: Histological Staining and Spore Concentration Procedures," Joseph O'Grodnick, 10:30-31.
1342. "Some Protozoan Diseases of Decapod Crustaceans," Thomas K. Sawyer and Sharon A. MacLean, 10:32-34.
1343. "The Principal Parasitic Diseases of Warmwater Fishes," W. A. Rogers, 10:35-36.
1344. "Trypanorhynch Infections in the Flesh of Sciaenid Fishes," Robin M. Overstreet, 10:37-38.
1345. "Larval Nematodes Parasitic in Shellfish," Thomas C. Cheng, 10:39-42.
1346. "Environmentally Related Diseases of Marine Fish and Shellfish," Carl J. Sindermann, 10:43
1347. "Nutrient Requirement of the Lobster and Nutrition Pathology," Robert C. Bayer, Margie Lee Gallagher, and Dale F. Leavitt, 10:44.
1348. "Nutritionally Induced Cataracts in Salmonids Fed Purified and Practical Diets," Hugh A. Poston, Ronald C. Riis, Gary L. Rumsey, and H. George Ketola, 10:45
1349. "Environmental Parameters Affecting Fish Physiology in Water Reuse Systems," Thomas L. Meade, 10:46
1350. "PCB-Induced Alterations in Teleost Liver: A Model for Environmental Disease in Fish," David E. Hinton, James E. Klaunig, and Michael M. Lipsky, 10:47-50.
1351. "A Review of Histopathological Effects of Selected Contaminants on Some Marine Organisms," George R. Gardner, 10:51-52.

NOVEMBER

1352. "Scallops and Their Utilization," John A. Peters, 11:1-9.
1353. "Blue Crab Larval Culture: Methods and Management," Mark R. Millikin, 11:10-17.
1354. "The 1976 Catch of Bowhead Whales, *Balaena mysticetus*, by Alaskan Eskimos," Willman M. Marquette, 11:18-27.

DECEMBER

1355. "Composition of the Edible Portion of Raw (Fresh or Frozen) Crustaceans, Finfish, and Mollusks. IV. Vitamins," Virginia D. Sidwell, Audrey L. Loomis, Pauline R. Foncannon, and David H. Buzzell, 12:1-16.
1356. "Review of Oxygen Depletion and Associated Mass Mortalities of Shellfish in the Middle Atlantic Bight in 1976," Frank W. Steimle and Carl J. Sindermann, 12:17-26.

Editorial Guidelines for *Marine Fisheries Review*

Marine Fisheries Review publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 6, "A List of Common and Scientific Names of Fishes from the United States and Canada," third edition, 1970. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Citations

Title the list of references "Literature Citations" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, the year and month and volume and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

Citations should be double-spaced and listed alphabetically by the senior author's surname and initials. Co-authors should be listed by initials and surname. Where two or more citations have the same author(s), list them chronologically; where both author and year match on two or more, use lowercase alphabet to distinguish them (1969a, 1969b, 1969c, etc.).

Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8- × 10- inches, sharply focused glossies of strong contrast. Potential cover photos are welcome but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 1107 N.E. 45th Street, Room 450, Seattle, WA 98105.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 100 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.

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